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MSFC SKYLAB COROLLARY EXPERIMENT SYSTEMS MISSION EVALUATION

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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NONSTANDARD ABBREVIATIONS

AA	Aerosol analyzer
ACAD	Automatic camera actuator device
AM	Airlock module
AMS	Articulated mirror system
AP	Automatic programmer
ARC	Ames Research Center
ASAP	Auxiliary storage and playback assembly
ATM	Apollo telescope mount
CAPCOM, CC	Capsule communicator
CDR	Commander
CG	Center of gravity
CM	Command module
CMG	Control moment gyroscope
CPMD	Charged particle mobility device
CS	Crew station
CSM	Command/service module
DAC	Data acquisition camera
DCS	Digital command system
DOY	Day of year
EDM	Engineering development model
EDS	Experiment data system
EREP	Earth resources experiment package
EVA	Extra-vehicular activity

FAS	Fixed airlock shroud
FCMU	Foot-controlled maneuvering unit
FMU	Force measuring unit
FMS	Force measuring system
FMT	Flight management team
FO	Functional objective
FOV	Field of view
GET	Ground elapsed time
GCR	Galactic cosmic radiation
GMT	Greenwich mean time
HOSC	Huntsville Operations Support Center
ICD	Interface control drawing
ID	Identification
IMSS	In-flight medical support system
IR	Infrared
IU	Instrument unit
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LIMS	Limb motion sensing assembly
LST	Large space telescope
LSU	Life support umbilical
MD	Mission day
MDA	Multiple docking adapter
MRD	Mission requirements document

MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OA	Orbital assembly
ODB	Operational data book
OWS	Orbital workshop
PI	Principal investigator
PLT	Pilot
PMT	Photomultiplier tube
PRD	Personal radiation dosimeter
PSS	Propellant supply subsystem
QCM	Quartz crystal microbalance
QLDS	Quick-look data station
RCS	Reaction control system
SA	Sample array
SAA	South Atlantic anomaly
SAL	Scientific airlock
SKYBET	Skylab best estimate trajectory
SMMD	Specimen mass measurement device
SOP	Secondary oxygen pack
SPT	Science pilot
SWC	Solar wind composition
S&E	Science & Engineering Laboratories (MSFC)
SL-1	First Skylab mission (unmanned)
SL-2	Second Skylab mission (manned)
SL-3	Third Skylab mission (manned)

SL-4	Fourth Skylab mission (manned)
TM	Technical memorandum
TV	Television
UM	Universal mount
UV	Ultraviolet
VDC	Volts, direct current
VTR	Video tape recorder (recording)
W-PAFB	Wright-Patterson Air Force Base
X	Vehicle axis (roll)
Y	Vehicle axis (pitch)
Z	Vehicle axis (yaw)

TECHNICAL MEMORANDUM X-64820

MSFC SKYLAB COROLLARY EXPERIMENTS SYSTEMS MISSION EVALUATION REPORT

SECTION I. SUMMARY

The performance of corollary experiment hardware developed by the George C. Marshall Space Flight Center and operated during the three manned Skylab missions is evaluated, and assessments are made of the functional adequacy of the experiment hardware and its supporting systems. Hardware evaluations are limited to discussions of experiment operations, as influenced by experiment and carrier systems, and indications are given as to the degrees by which experiment constraints and interfaces were met. Operational anomalies are also identified, and impact assessments are given as they affected experiment objectives.

As indicated in this report, most of the corollary experiment hardware performed satisfactorily and within design specifications. For the most part, each corollary experiment achieved practically all of its functional objectives and, in the case of a large number of these experiments, additional objectives were achieved resulting in supplementary experiment scientific data. Operational modifications and work-arounds were made to those few corollary experiments designed to operate through the solar scientific airlock. These modifications were necessary because of the initial loss of a portion of the workshop meteoroid shield and the subsequent deployment of a protective "parasol" covering through this airlock. Discussions of the necessary experiment work-arounds are presented.

No attempt has been made in this report to present indications of the quality of experiment scientific data returned from Skylab for postflight analysis, and no indications are given as to preliminary interpretations of the data. Experiment findings and conclusions will be published by the respective corollary experiment Principal Investigators at later dates.

SECTION II. INTRODUCTION

A. Purpose

This document provides descriptions of those Skylab corollary experiments for which the George C. Marshall Space Flight Center (MSFC) had prime or proxy development responsibility, and presents assessments of the functional adequacy of experiment flight hardware and supporting systems during in-flight operations. Also presented are indications of the degrees to which experiment constraints and interfaces were met, and identifications are made of the types and quantities of experiment scientific data obtained and returned to earth for postflight analysis. Data analysis is presently in progress and comprehensive reports of experiment findings and conclusions will be published by the experiment Principal Investigators (PI) at later dates.

B. Scope

Of 94 experiments approved for Skylab, MSFC had prime or proxy development responsibility for 51, including 11 Student Project experiments for which flight hardware was required. For the purposes of this report, "MSFC developed" experiments include the experiments developed by the Langley Research Center, as well as those from the Ames Research Center, the Department of Transportation and the Department of Defense for which MSFC was designated "proxy development center." The 51 MSFC-developed corollary experiments are discussed in Sections III through VI of this report, where each experiment is evaluated in accordance with a common organizational outline. The outline used is summarized as follows:

Experiment Number and Title: Identifications are made of the PI, Experiment Developer, and their organization affiliations and respective locations.

Experiment Description: Brief descriptions of experiment objectives and concept are presented, along with identifications and functions of experiment hardware elements.

Experiment Operation: For each mission on which the respective experiments were performed, comparisons are made between planned versus actual operations.

Constraints: All violations of operational and scheduling constraints established in the Mission Requirements Document (MRD), Operational Data Book (ODB), Mission Rules, etc. are identified and their impact discussed.

Hardware Performance: Descriptions are provided of hardware performances of each element. Where applicable, operational anomalies are identified.

Interfaces: All Interface Control Drawing (ICD) requirement violations are identified and their impact discussed.

Return Data: Identifications are made of the types and quantities of experiment scientific data returned to earth and delivered to the respective PIs for postflight analysis.

Anomalies: Detailed descriptions and analyses of experiment anomalies noted during the missions are presented.

One experiment and six science demonstrations were not performed due to launch or crew time limitations. A brief description of these is included, but since they were not performed, the last five paragraphs in the preceding outline are omitted.

It should be emphasized that this document covers the evaluations and assessments of MSFC-developed experiment hardware only, and that no attempt is made to analyze or draw conclusions from the experiment scientific data obtained from Skylab. Proprietary rights to the scientific data have been granted to the Principal Investigators, and reports of their findings will become available in accordance with previously agreed upon publication schedules.

It should also be noted that the corollary experiments made use of support equipment which, in general, is not discussed herein. Several experiments used operational photographic equipment and film provided by Lyndon B. Johnson Space Center (JSC) to record their data. Performances of this equipment is covered in the JSC Skylab Mission Reports (First Visit, JSC-08414; Second Visit, JSC-08662; and Third Visit, JSC-08963.) and is discussed herein only as necessary to describe operations and anomalies impacting the MSFC developed experiments. The period of high temperatures during the several days after SL-1 launch had a potential impact on all film. This anomaly and the radiation protection afforded by the OWS film vault are discussed in Appendix A.

The Scientific Airlocks (SAL) located in the Orbital Work Shop (OWS) supported several experiments. The use of the solar SAL for deployment of the parasol solar shield early in SL-2 precluded normal operation of the experiments scheduled to use this SAL. A description of the SALs, and the desiccant and filter systems, is presented along with an assessment of their performances in the MSFC Skylab Orbital Workshop Final Technical Report (TMX-64813). A number of experiments utilized the Articulated Mirror System (AMS) which was developed for JSC in conjunction with Experiment S019, UV Stellar Astronomy, and aided viewing of desired targets (e.g., Comet Kohoutek) with minimal spacecraft maneuvers.

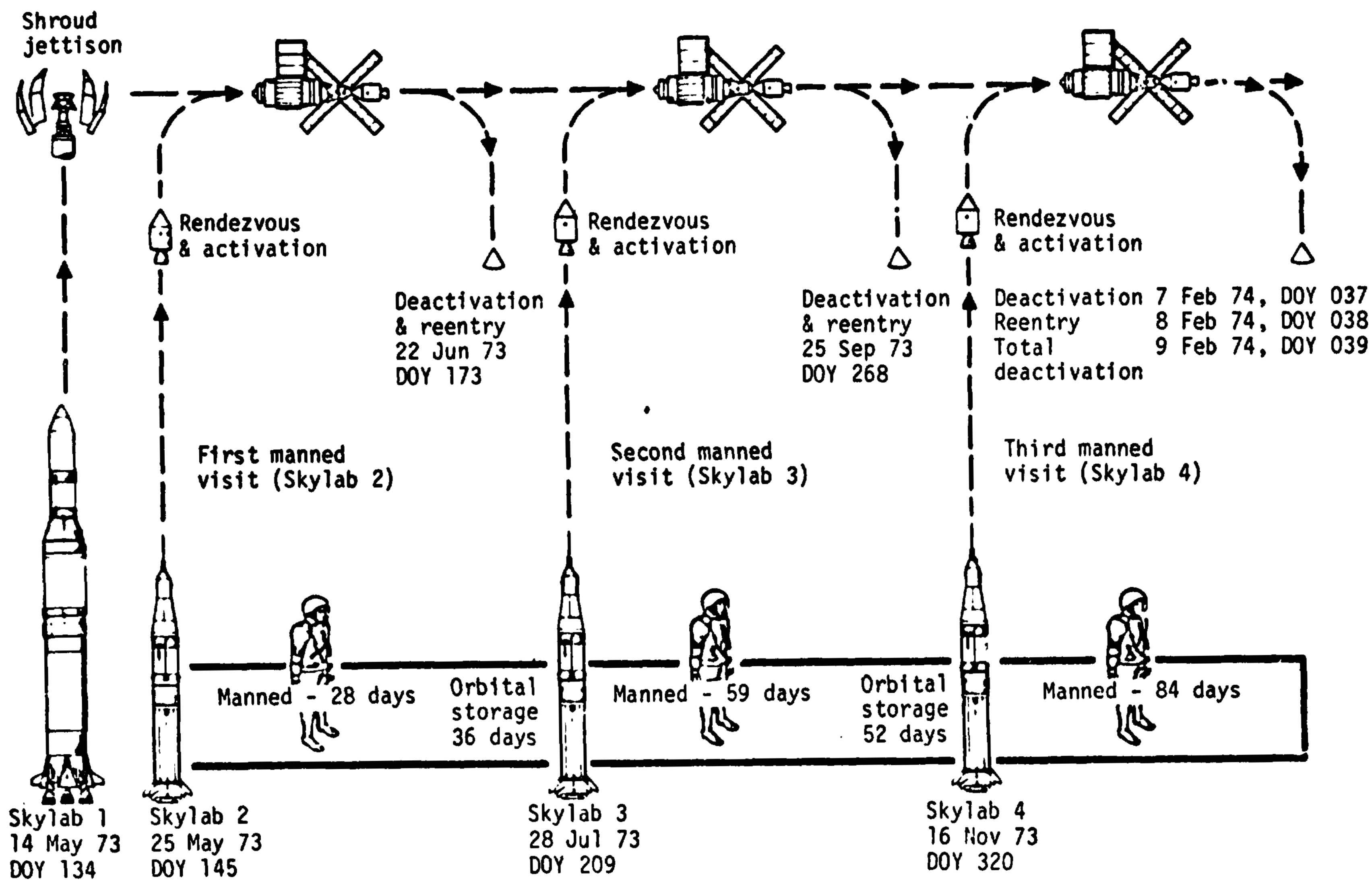

FIGURE II-1 SKYLAB MISSION PROFILE

C. Mission History

The mission operations phase of the Skylab Program began on May 14, 1973 (1:30 pm EDT) with the launch of the unmanned Saturn Workshop aboard a Saturn V launch vehicle from Kennedy Space Center, Florida. As shown in figure II-1, the mission operations phase continued with three subsequent launches of three-man crews aboard Saturn IB launch vehicles, who rendezvoused with Skylab and occupied it for extended periods up to 84 days. The mission operations phase continued through February 9, 1974, as illustrated in figure II-1.

During the three manned visits to Skylab, each three-man crew initially set up housekeeping and proceeded to perform numerous scientific experiments and investigations throughout the remainder of their visit. Experiments performed were categorized within the following disciplines: biomedical; earth resources; solar physics; and corollary. This latter discipline of MSFC-developed experiments is covered in this mission evaluation report.

Pre-mission planning scheduled orbital insertion of the Workshop approximately 10 minutes following liftoff (SL-1 mission) on May 14, 1973. Planning also provided for activation of certain on-board systems and deployment of the massive Apollo Telescope Mount (ATM) and

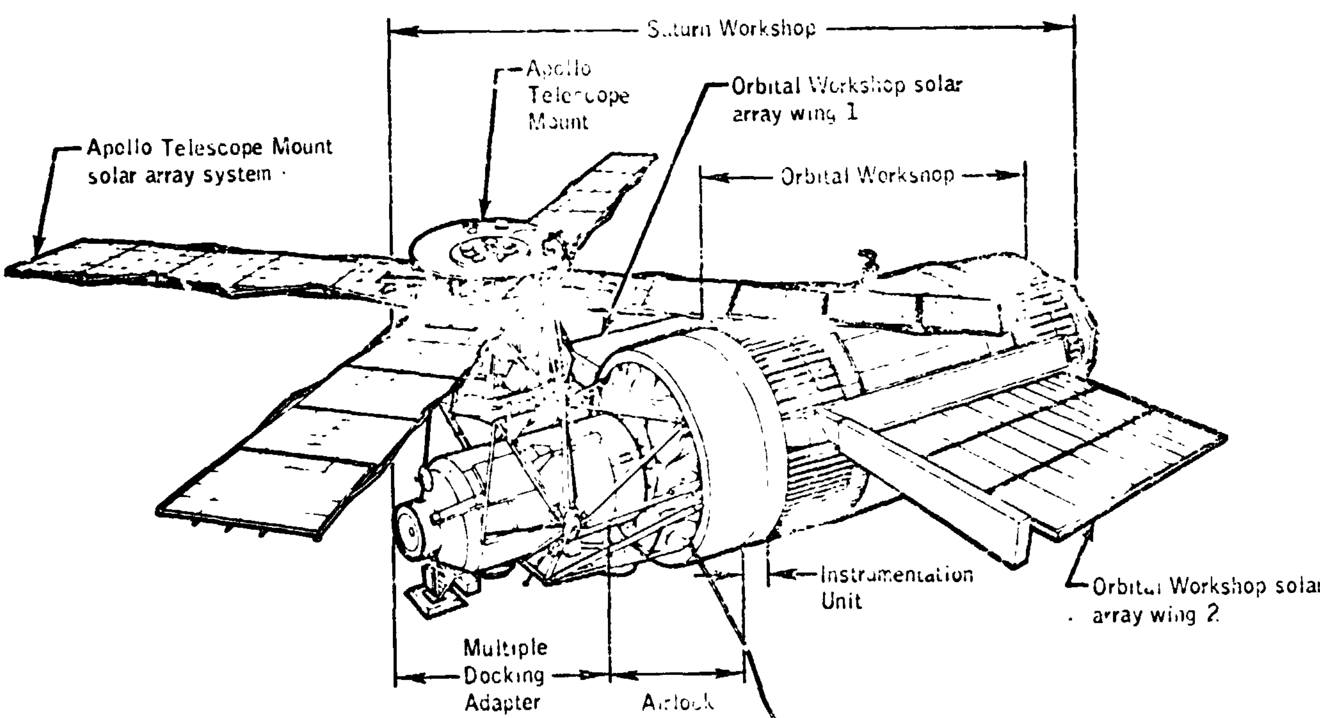

FIGURE II-2 SKYLAB ORBITAL ASSEMBLY

two Workshop solar array wings prior to the launch of the first visit crew (SL-2 mission) scheduled for the following day (May 15, 1973). The planned configuration of the Skylab orbital assembly is shown in figure II-2.

An unexpected indication of problems involving meteoroid shield and solar array deployment was received approximately one minute following lift-off of the SL-1 launch vehicle. Ground investigations revealed that the Workshop had sustained damage during the launch phase which resulted in the loss of the meteroid shield and one of the solar array wings. Investigations also revealed that the second solar array wing had sustained damage and had only been partially deployed. Immediate effects of these conditions were reduced power and higher-than-expected internal temperature levels within the Workshop. Launch of the SL-2 manned vehicle was postponed until May 25, 1973, to allow more time for assessing Workshop damage and to develop appropriate fixes.

Following a normal launch of the manned SL-2 launch vehicle on May 25, 1973, the first three-man crew docked to the Workshop after visually inspecting the damaged sections, and entered the cluster to begin a 28-day visit. During the early days of the SL-2 visit the crew was successful in deploying a thermal shield over the exposed Workshop skin, and in freeing the partially deployed solar array wing. The immediate results were a slow reduction of internal temperatures to specified values and an increase in the available power level. The remainder of the SL-2 mission was accomplished as planned. Subsequent visits by the second and third crews (SL-3 and SL-4 visits) were performed nominally.

Throughout the three visits, planned experiments and investigations were carried out with relatively minor modifications required. Discussions of the required experiment modifications and "work-arounds" are presented in Section III through VI of this report.

D. Conversion Data

Throughout this report. experiment performance times and events are expressed as "days of year" or "mission days". Figure II-3 provides the reader with a means for comparing calendar and mission days, and for converting these days to the appropriate days of the year.

DAY	DATE (1973)	DOY	MISSION PERIODS
1	5-14	134	(FIRST UNMANNED PERIOD)
2	5-15	135	
3	5-16	136	
4	5-17	137	
5	5-18	138	
6	5-19	139	
7	5-20	140	
8	5-21	141	
9	5-22	142	
10	5-23	143	
11	5-24	144	
12	5-25	145	1 FIRST MANNED PERIOD MISSION DAYS
13	5-26	146	2
14	5-27	147	3
15	5-28	148	4
16	5-29	149	5
17	5-30	150	6
18	5-31	151	7
19	6-1	152	8
20	6-2	153	9
21	6-3	154	10
22	6-4	155	11
23	6-5	156	12
24	6-6	157	13
25	6-7	158	14
26	6-8	159	15
27	6-9	160	16
28	6-10	161	17
29	6-11	162	18
30	6-12	163	19
31	6-13	164	20
32	6-14	165	21
33	6-15	166	22
34	6-16	167	23
35	6-17	168	24
36	6-18	169	25
37	6-19	170	26
38	6-20	171	27
39	6-21	172	28
40	6-22	173	29
41	6-23	174	(SECOND UNMANNED PERIOD)
42	6-24	175	
43	6-25	176	
44	6-26	177	
45	6-27	178	
46	6-28	179	
47	6-29	180	
48	6-30	181	
49	7-1	182	
50	7-2	183	
51	7-3	184	
52	7-4	185	
53	7-5	186	
54	7-6	187	
55	7-7	188	
56	7-8	189	
57	7-9	190	
58	7-10	191	
59	7-11	192	
60	7-12	193	
61	7-13	194	
62	7-14	195	
63	7-15	196	
64	7-16	197	
65	7-17	198	
66	7-18	199	
67	7-19	200	
68	7-20	201	
69	7-21	202	

DAY	DATE (1973)	DOY	MISSION PERIODS
70	7-22	203	
71	7-23	204	
72	7-24	205	
73	7-25	206	
74	7-26	207	
75	7-27	208	
76	7-28	209	1 SECOND MANNED PERIOD MISSION DAYS
77	7-29	210	2
78	7-30	211	3
79	7-31	212	4
80	8-1	213	5
81	8-2	214	6
82	8-3	215	7
83	8-4	216	8
84	8-5	217	9
85	8-6	218	10
86	8-7	219	11
87	8-8	220	12
88	8-9	221	13
89	8-10	222	14
90	8-11	223	15
91	8-12	224	16
92	8-13	225	17
93	8-14	226	18
94	8-15	227	19
95	8-16	228	20
96	8-17	229	21
97	8-18	230	22
98	8-19	231	23
99	8-20	232	24
100	8-21	233	25
101	8-22	234	26
102	8-23	235	27
103	8-24	236	28
104	8-25	237	29
105	8-26	238	30
106	8-27	239	31
107	8-28	240	32
108	8-29	241	33
109	8-30	242	34
110	8-31	243	35
111	9-1	244	36
112	9-2	245	37
113	9-3	246	38
114	9-4	247	39
115	9-5	248	40
116	9-6	249	41
117	9-7	250	42
118	9-8	251	43
119	9-9	252	44
120	9-10	253	45
121	9-11	254	46
122	9-12	255	47
123	9-13	256	48
124	9-14	257	49
125	9-15	258	50
126	9-16	259	51
127	9-17	260	52
128	9-18	261	53
129	9-19	262	54
130	9-20	263	55
131	9-21	264	56
132	9-22	265	57
133	9-23	266	58
134	9-24	267	59
135	9-25	268	60
136	9-26	269	
137	9-27	270	

DAY	DATE (1973)	DOY	MISSION PERIODS
138	9-28	271	(THIRD UNMANNED PERIOD)
139	9-29	272	
140	9-30	273	
141	10-1	274	
142	10-2	275	
143	10-3	276	
144	10-4	277	
145	10-5	278	
146	10-6	279	
147	10-7	280	
148	10-8	281	
149	10-9	282	
150	10-10	283	
151	10-11	284	
152	10-12	285	
153	10-13	286	
154	10-14	287	
155	10-15	288	
156	10-16	289	
157	10-17	290	
158	10-18	291	
159	10-19	292	
160	10-20	293	
161	10-21	294	
162	10-22	295	
163	10-23	296	
164	10-24	297	
165	10-25	298	
166	10-26	299	
167	10-27	300	
168	10-28	301	
169	10-29	302	
170	10-30	303	
171	10-31	304	
172	11-1	305	
173	11-2	306	
174	11-3	307	
175	11-4	308	
176	11-5	309	
177	11-6	310	
178	11-7	311	
179	11-8	312	
180	11-9	313	
181	11-10	314	
182	11-11	315	
183	11-12	316	
184	11-13	317	
185	11-14	318	
186	11-15	319	
187	11-16	320	1 THIRD MANNED PERIOD MISSION DAYS
188	11-17	321	2
189	11-18	322	3
190	11-19	323	4
191	11-20	324	5
192	11-21	325	6
193	11-22	326	7
194	11-23	327	8
195	11-24	328	9
196	11-25	329	10
197	11-26	330	11
198	11-27	331	12
199	11-28	332	13
200	11-29	333	14
201	11-30	334	15
202	12-1	335	16
203	12-2	336	17
204	12-3	337	18
205	12-4	338	19

DAY	DATE (1973-74)	DOY	MISSION PERIODS
206	12-5	339	20 THIRD MANNED PERIOD MISSION DAYS (CONTINUED)
207	12-6	340	21
208	12-7	341	22
209	12-8	342	23
210	12-9	343	24
211	12-10	344	25
212	12-11	345	26
213	12-12	346	27
214	12-13	347	28
215	12-14	348	29
216	12-15	349	30
217	12-16	350	31
218	12-17	351	32
219	12-18	352	33
220	12-19	353	34
221	12-20	354	35
222	12-21	355	36
223	12-22	356	37
224	12-23	357	38
225	12-24	358	39
226	12-25	359	40
227	12-26	360	41
228	12-27	361	42
229	12-28	362	43
230	12-29	363	44
231	12-30	364	45
232	12-31	365	46
233	1-1	1	47
234	1-2	2	48
235	1-3	3	49
236	1-4	4	50
237	1-5	5	51
238	1-6	6	52
239	1-7	7	53
240	1-8	8	54
241	1-9	9	55
242	1-10	10	56
243	1-11	11	57
244	1-12	12	58
245	1-13	13	59
246	1-14	14	60
247	1-15	15	61
248	1-16	16	62
249	1-17	17	63
250	1-18	18	64
251	1-19	19	65
252	1-20	20	66
253	1-21	21	67
254	1-22	22	68
255	1-23	23	69
256	1-24	24	70
257	1-25	25	71
258	1-26	26	72
259	1-27	27	73
260	1-28	28	74
261	1-29	29	75
262	1-30	30	76
263	1-31	31	77
264	2-1	32	78
265	2-2	33	79
266	2-3	34	80
267	2-4	35	81
268	2-5	36	82
269	2-6	37	83
270	2-7	38	84
271	2-8	39	85
TESTS & ORBITAL STORAGE			
272	2-9	40	
273	2-10	41	

FIGURE II-3 CONVERSION DATA

SECTION III. ASTRONOMY AND SCIENCE EXPERIMENTS

A. Experiment S009-Nuclear Emulsion

The Principal Investigator for Experiment S009 is Dr. Maurice M. Shapiro, Chief Scientist, Laboratory for Cosmic-Ray Physics, Naval Research Laboratory (NRL), Washington, D.C. The Engineering Services Division, NRL, was the Experiment Developer.

1. Experiment Description. Nucleogenesis theories predict the relative abundances of nuclei that would be produced in thermonuclear reactions occurring in such possible sources as neutron stars. It is of great interest to study these extremely high velocity nuclei (cosmic rays) approaching the earth. The Skylab mission provided the experiment with an adequate exposure in space to determine statistically the abundances and energy spectra of the heavy, primary cosmic-ray nuclei.

a. Objectives. The objective was to record the primary cosmic ray flux incident upon the top of the earth's atmosphere, especially the relative abundances and energy spectra of heavy nuclei in the range of atomic numbers from 16 to 28.

b. Concept. The experiment was to be carried into space to detect the particles before they interacted with the earth's atmosphere to generate secondary particles and to obtain an accurate measure of the primary cosmic ray flux.

The experiment was to be composed of a multi-layered nuclear emulsion package which would provide data through particle impact, penetration and direction. The abundances, energies and charges of the cosmic-ray nuclei can be determined by measuring the variations in thickness and direction of the tracks left by the cosmic rays in the layers of the returned emulsion package.

From the numbers of particles recorded at each value of energy and charge, the abundance ratios of particular nuclei, and the differences in abundance of nuclei with even and odd atomic numbers, some data can be obtained about the physical conditions where the nuclei were formed, the time that has elapsed since they were formed, and the nature of their interactions with interstellar material in transit.

c. Hardware Description. The experiment equipment included two adjacent stacks of nuclear emulsion strips (see figure III-1). The stacks were covered with thin teflon and aluminum foil to make them

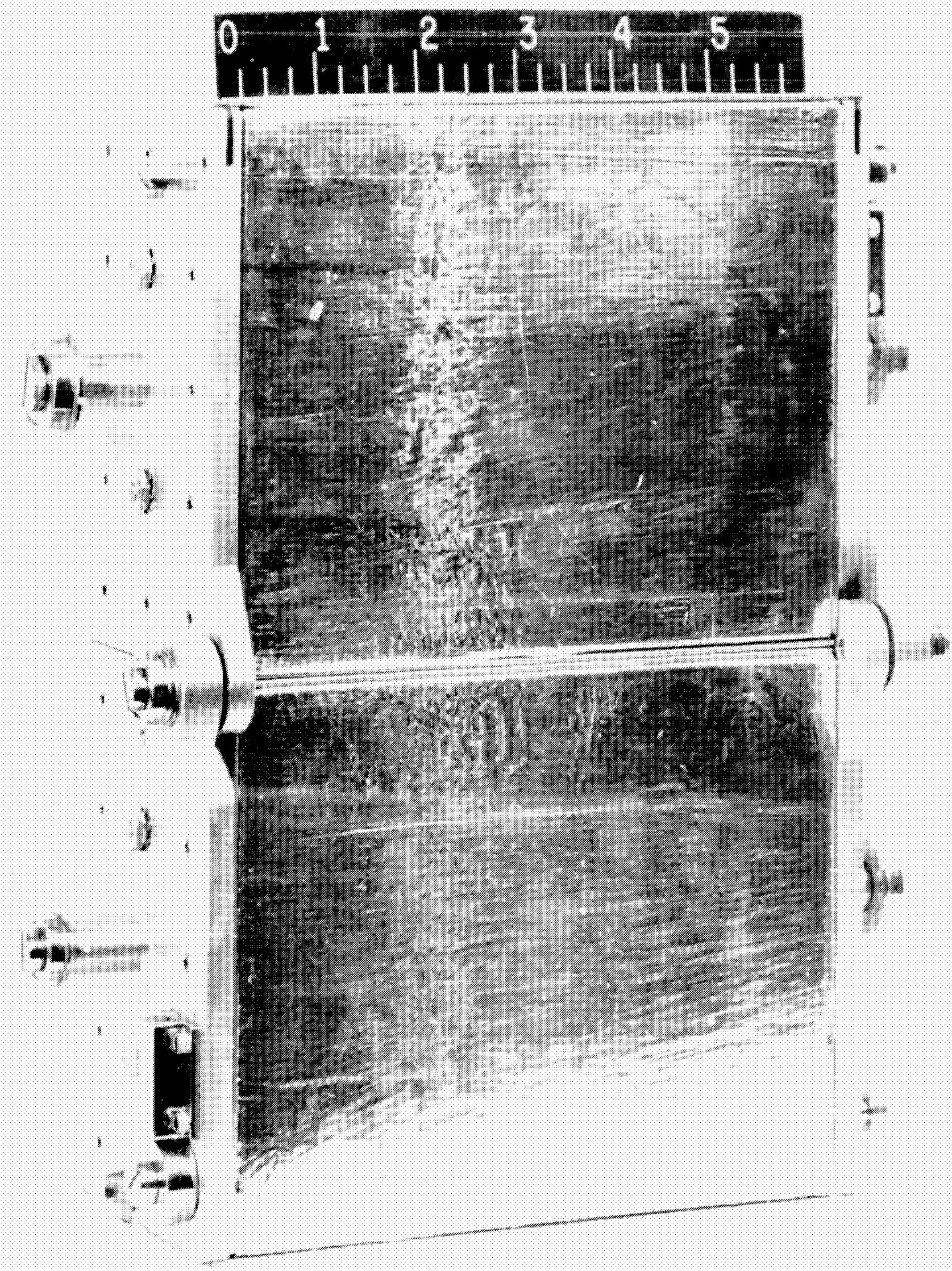

FIGURE III-1. S009 DETECTOR PACKAGE

light-tight and preserve their moisture content. The emulsions differed from regular photographic emulsions, being considerably thicker and containing a much higher density of silver halide, to improve the detection of tracks left by charged particles. The stacks were hinged together like two sides of an open book and contained several layers of different emulsion types.

During operation the detector package was deployed within the MDA against the wall on the +Y axis where the MDA aluminum skin had been chem-milled to a thickness of 0.2 centimeters (see figure III-2).

The detector package had a conical field-of-view of 0.38 radians. Experiment pointing could be changed plus and minus 1.3 radians in increments of 0.13 radians; however, the experiment housing structural members began to intrude into the field-of-view after approximately plus or minus one radian from the viewing axis. The experiment housing, control panel and BETA ANGLE ADJUST knob (located) at the bottom) are shown in figure III-3. The manual pointing adjustment permitted periodic compensation for beta angle changes.

2. Experiment Operations. Experiment initiation was performed by a crewman on a time reference from the ground when Skylab passed 30 degrees N latitude while traveling in a southerly direction. Thereafter, the opening and closing was automatically performed by the experiment. The experiment timing was monitored from crew comments, and the Skylab orbit track was followed by the ground to detect any accumulative errors in the emulsion package opening/ closing times. Large timing errors were corrected onboard by the crewman's resetting the PERIOD ADJUST potentiometer to the new value computed on the ground. Small errors were removed by daily re-initiates at a southward crossing of 30 degrees N latitude. The exact times (to the second) for these operations were provided the crew each morning; the new BETA ANGLE ADJUST setting was uplinked at the same time.

The detector package was opened to collect data whenever Skylab was in the equatorial zone between 30 degrees N and 25 S latitude; it was closed at all other times during the orbit. In the equatorial region only the highest-velocity (relativistic) cosmic-ray nuclei of interest to the S009 study penetrated the earth's magnetic field to Skylab's altitude and left tracks in the detector package. At the higher latitudes (both N and S) where the earth's magnetic field bends closer to the earth, heavy-but-slower nuclei (of lesser interest to this study) also penetrated to Skylab's altitude and left tracks in the detector package. By design, however, the package was closed in those regions and therefore all tracks recorded at those latitudes were recognizable by the fact that they crossed two exposure faces and could be discounted during analysis.

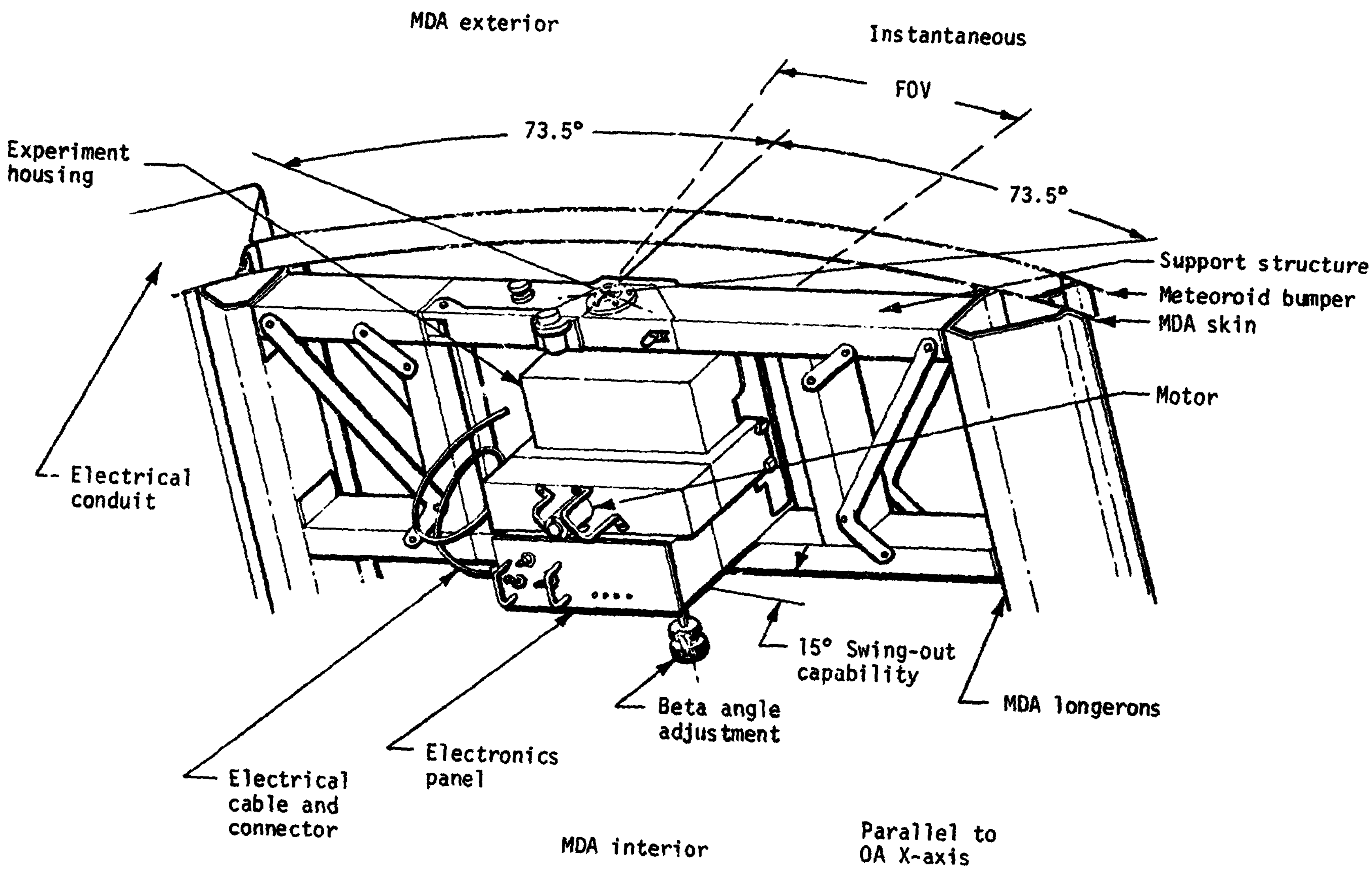

FIGURE III-2. S009 OPERATIONAL CONFIGURATION (MDA INTERIOR)

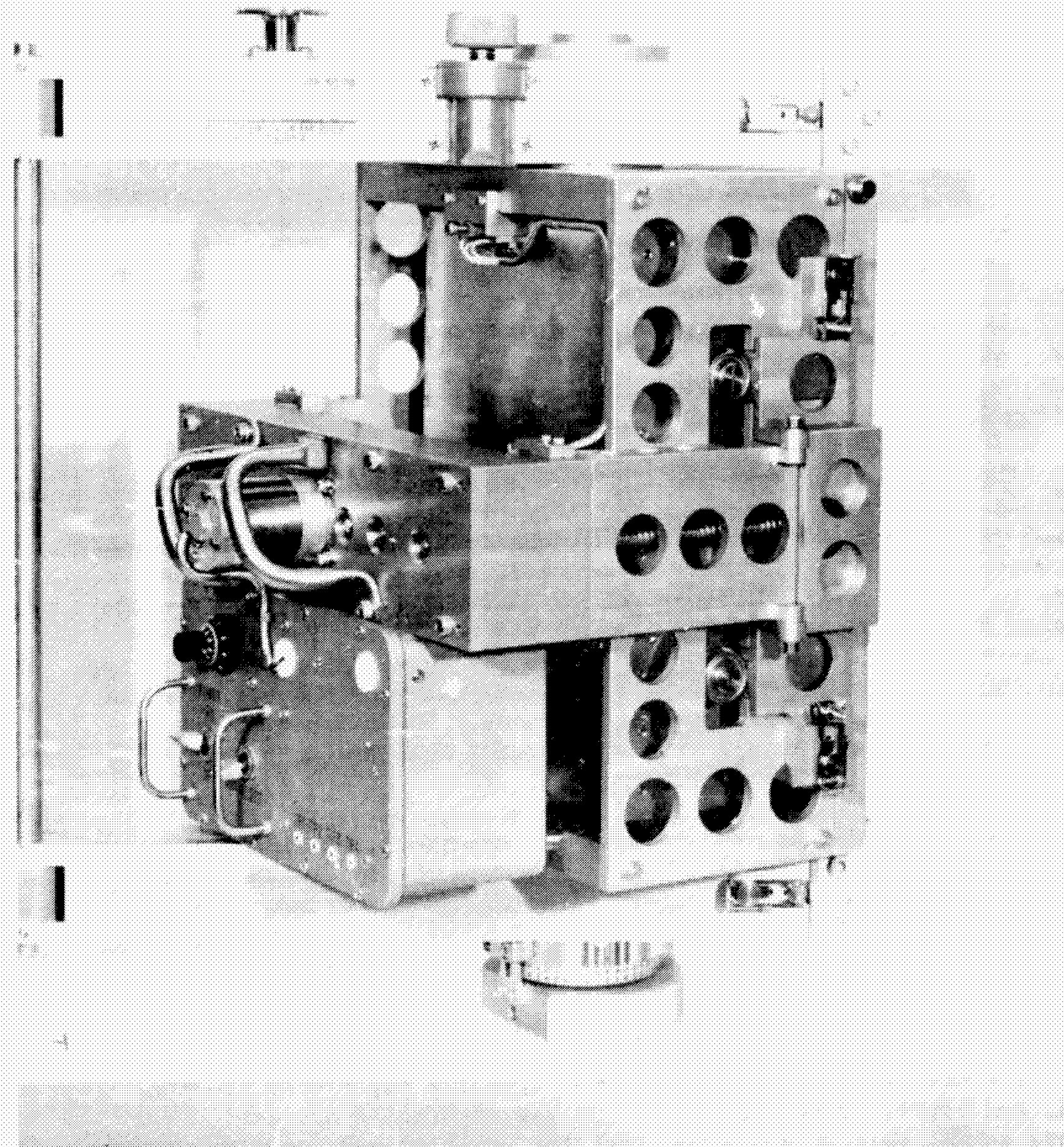

FIGURE III-3. S009 EXPERIMENT HOUSING

Package closure at 25 degree S latitude also provided partial shielding of the exposure faces from the trapped particle (Van Allen) radiation in the South Atlantic Anomaly.

a. SL-1/SL-2 Experiment Operation. The nuclear emulsion detector package was launched in the OWS film vault and was exposed to the high-temperature environment occasioned by the meteoroid shield failure. The decision was made to deploy the package to obtain whatever data was possible with the probably degraded emulsion. It was transferred from the film vault to the experiment housing in the MDA on DOY 149. The Pilot reported difficulty installing the package because of an extremely tight fit between it and the experiment housing. Nevertheless he accomplished the installation and initiated the automatic sequencing later that day.

Operation appeared normal for the next several days, although one timing check gave an indication of trouble. It indicated that the opening/closing cycle was out of synchronism by a considerable amount. The PERIOD ADJUST potentiometer was reset to correct the error. The crew was advised to observe S009 occasionally for malfunction indications due to the possibility of intermittent motor stalling resulting from the installation difficulties.

The emulsion package was observed to be closing hesitantly with occasional motor stall periods on DOY 161. Following this indication, the S009 ground teams defined six questions to be answered by the crew. These were designed to elaborate on specific symptoms to narrow the problem to a motor stall or limit switch malfunction. The crew answers indicated that an apparent motor failure had occurred. However, as a final check a malfunction procedure was uplinked, detailing an operating mode (without the detector package installed) using manual operation of the fully-opened, fully-closed limit switches. The PLT performed the malfunction procedure and it was concluded that the motor had weakened to the point of failure.

The PI decided to proceed with the experiment to gain the maximum scientific data during the mission even though the automatic opening/closing cycle was no longer operable. The experiment was deployed without power in the opened position for the remainder of SL-2. This operational method was obviously not as desirable because the discrimination mechanism was inoperable. Manual repointing for beta angle changes was continued during this period, however.

The detector package was removed from the experiment housing, folded, and stowed in the CM on DOY 170 for return. Subsequent analysis at NRL quickly confirmed that the emulsion had been irreparably damaged by the exposure to the excessively high temperatures. A request was made for approval of a new detector package and a replacement motor for the experiment housing for SL-3.

b. SL-3 Experiment Operation. No experiment operation was possible because the detector package, although approved for SL-3, was replaced by higher-priority items. However, a replacement motor was supplied but not installed on this mission.

c. SL-4 Experiment Operation. The new detector package was resupplied for SL-4. Since it would remain aloft for 84 days (rather than 28 days) in a high-radiation environment it was purposely built-up using a greater percentage of less-sensitive emulsions than the original detector package.

The motor resupplied on SL-3 was installed by the CDR on DOY 330. Normal performance was immediately restored as evidenced by restoration of motor drive operation when the limit switches were actuated. The new detector package was installed and experiment operation was continuous from DOY 330 to DOY 003. At this time the PI preferred stowing the detector package for return since sufficient data-taking time had been logged. Another reason was the indication that the package opening/closing cycle synchronization was failing, based upon timing checks on DOYs 360 and 365. The motor was not stalling but timing system drift was suspected. The experiment would have been terminated on DOY 009 in any case because Skylab was moving into a period of beta angles in excess of one radian. The beta angle history during the mission and the use of the stepwise BETA ANGLE ADUST settings to compensate for changing beta angle are shown in figure III-4.

3. Experiment Constraints. The experiment constraints were successfully met during the mission except that the temperature was exceeded on SL-1/SL-2 as noted earlier due to the meteoroid shield loss. The experiment operating constraint (taking data between 30 degrees N latitude to 25 degrees S latitude) was violated during SL-2 operations when the motor failed and the package was placed in an open position until retrieval. This constraint was met during SL-4.

4. Hardware Performance. The heat-damaged detector package exhibited a prohibitively tight fit upon installation and during subsequent operation. The SL-4 resupplied detector package performed satisfactorily.

The manual beta angle adjustment functioned properly to permit periodic compensation for changes in the beta angle.

The experiment timing system performed satisfactorily until a related problem occurred during SL-2. The timing system provided the signal for the motor to open and close the detector package at the proper latitudes. When the motor began to hesitate and stall, however, the timer did not receive the fully opened/closed limit switch signals from the experiment and therefore lost its event reference. The timing system resumed normal operation during SL-4 after the failed motor was replaced.

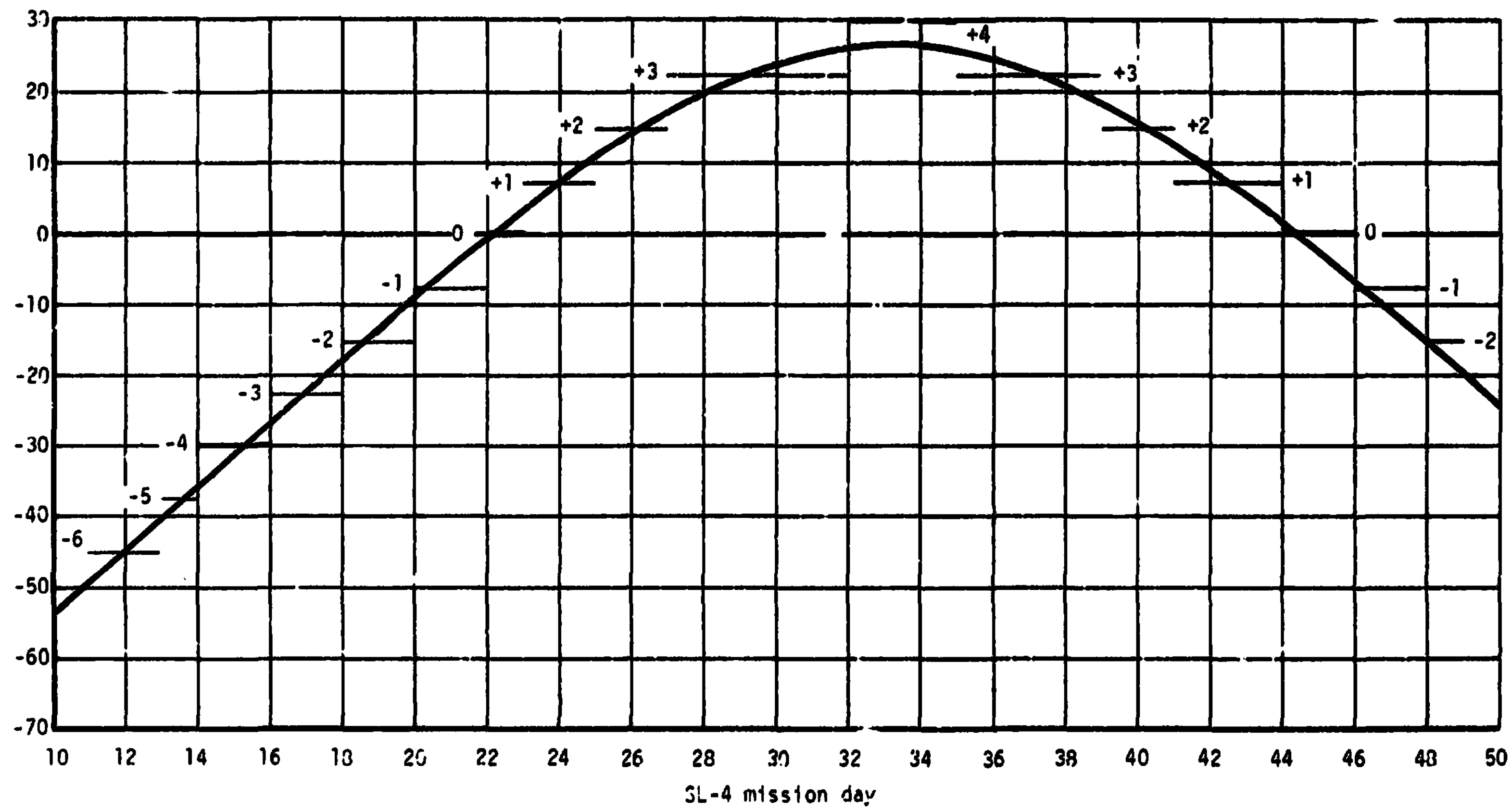

FIGURE III-4. BETA ANGLE HISTORY AND S009 BETA ANGLE ADJUST SETTINGS DURING SL-4

The motor/drive train was observed to be closing the detector package with difficulty and occasional stalling on DOY 161. A malfunction procedure (involving manual actuation of the limit switches) was performed by the crew and its results indicated that the motor had failed. A replacement motor was sent with the SL-3 crew but was not installed until DOY 330 during SL-4. The replacement motor restored the package opening/closing function.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission except for the detector package stowage temperature in the OWS film vault during SL-1/SL-2. This temperature exceeded its maximum limits rendering the emulsion material unsatisfactory for data analysis.

6. Return Data. Both detector packages were returned to the PI. The SL-2 detector package had been damaged severely by exposure to heat. Its individual emulsion layers had melted and then fused into a solid block preventing separation for analysis. The SL-4 detector package was not subjected to anomalous environments and performed as scheduled. It is being analyzed at NRL.

The following supplementary data was provided:

Periodic timing checks to corroborate the synchronism of the detector package opening/closing cycle,

Spacecraft pointing data to determine off-nominal pointing time,

Temperature history of the OWS film vault during SL-1/SL-2 stowage and the MDA interior during SL-4 operation,

Voice transcipts and post-flight crew debriefing comments.

The following post-flight crew debriefing comments are of interest, especially as concerns inflight maintenance:

CARR S009 - Nuclear Emulsion: Stowage and Unstowage. Bill unstowed and I stowed the unit without any problems. Motor replacement was no problem. The procedures went well. That was a good demonstration of how a man can get in there and cut wires and do splicing, and do a good job. I was really pleased to be able to do that. The motor replacement and the tools that were available for that prodded me to make some observations on M487, in the area of maintainability and maintenance. To reiterate, the tools on a spacecraft should include the proper tools for crimping and splicing wires.

7. <u>Anomalies</u>. The SL-2 detector package encountered two problems during the SL-1/SL-2 missions, but the resupplied package performed well during the SL-4 mission.

a. SL-1/SL-2 Anomalies. SL-1/SL-2 detector package was subjected to abnormally high temperatures. This resulted in the emulsion stack's individual layers softening and sticking together to the extent that they could not be separated for post-flight analysis. Further, the emulsion background fogging level had increased by a factor of at least two. These effects were predicted (based upon laboratory tests conducted at NRL) as soon as the temperature anomaly became known. Test samples, from the same emulsion batch as that in the flight nuclear emulsion package, were subjected to 120°F for 24 hours. A sticking and fogging problem was evident in that time period. Before parasol deployment, the temperatures aloft were over 90°F for 13 days which included five days between 120°F and 125°F.

A fresh nuclear emulsion package was requested for the first manned launch (SL-2) but was not possible because of higher priority items. Resupply on SL-3 was requested and was initially approved. However, it was offloaded for higher priority items. Resupply was accomplished by SL-4.

The opening/closing mechanism stalling was probably caused by a too-tight fit between the detector package and the experiment housing resulting in an excessive loading of the motor when opening and closing the package. Another contributing factor to the tight fit on installation was that the detector package was warm (100°F) when removed from the OWS film vault, and the experiment housing was relatively cold (60°F).

The solution was the milling of those resupplied detector package portions which were the probable cause of the tight fit during SL-1/SL-2. These areas were identified by carefully conducted ground tests in the training unit experiment housing at NRL. The resupplied package never experienced the stall problem during the SL-4 operation with a new motor.

b. SL-4 Anomalies. No anomalies were encountered.

B. Experiment S150 - Galactic X-Ray Mapping

The Principal Investigator for Experiment S150 is Dr. William Kraushaar, Physics Department, University of Wisconsin, Madison, Wisconsin. The University of Wisconsin, International Business Machines and the Astronautics and Astrionics Laboratories, George C. Marshall Space Flight Center, were responsible for the experiment hardware development.

Information in this section was obtained from the following reports:

D. Smitherman, S150 Galactic X-Ray Experiment (S-IU-208/SL-3) Final Flight Events Summary and Anomaly Report, Astrionics Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama, October 15, 1973.

A. bunner, Preliminary Report, S150 X-Ray Astronomy Experiment, University of Wisconsin, Madison Wisconsin, November, 1973.

1. Experiment Description

a. Objectives. The objectives were to survey a portion of the sky for X-rays in the 200 to 10,000 electron-volt energy range, to determine the intensity, location and spectrum of each observed source and to measure the continuous X-ray background. The experiment results were to help answer questions concerning emission mechanisms in X-ray sources, the distance to the sources, and the nature of the interstellar medium.

b. Concept. The thin-window soft X-ray detector was to be launched on the SL-4 S-IVB IU. After CSM separation, the S-IVB would orbit in an earth oriented mode and be rolled to attitudes that would permit the instrument to scan successive portions of the sky. Data from proportional counters with pulse height analyzers was to be recorded on magnetic tape and played back when the IU was in ground communication.

c. Hardware Description. The experiment sensor and supporting flight hardware were installed on S-IU-208/SL-3 (see figure III-5). The experiment flight hardware subsystems are shown in figure III-6, and are described in the following paragraphs:

(1) Experiment Sensor. The experiment sensor was basically a continuous-flow gas proportional counter assembly. The assembly included nine viewing counters, thirteen veto counters, charge amplifiers, low and high voltage supplies, and a constant density P-10 gas (90% argon, 10% methane) regulator. The assembly

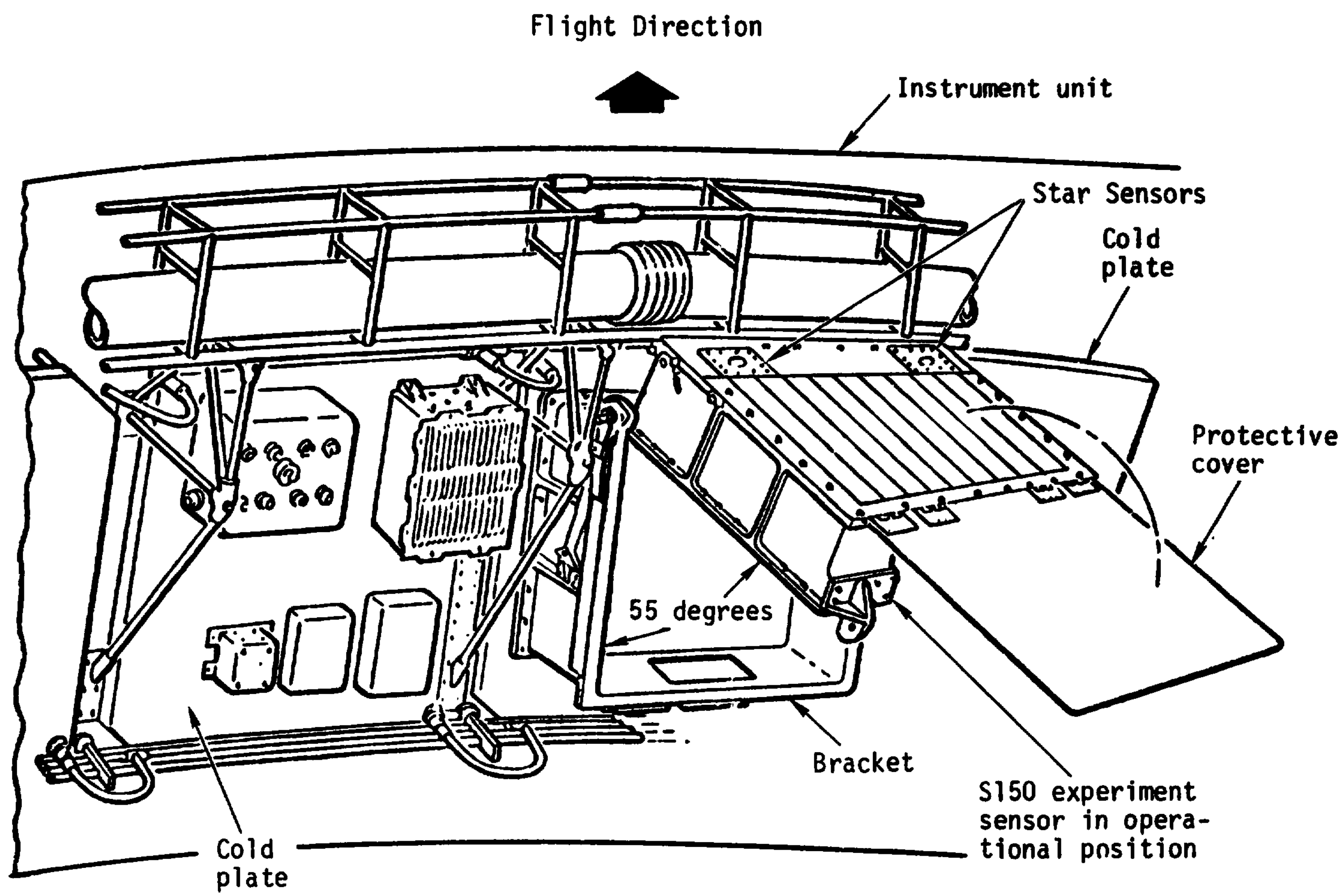

FIGURE III-5. S150 EXPERIMENT SENSOR DEPLOYED

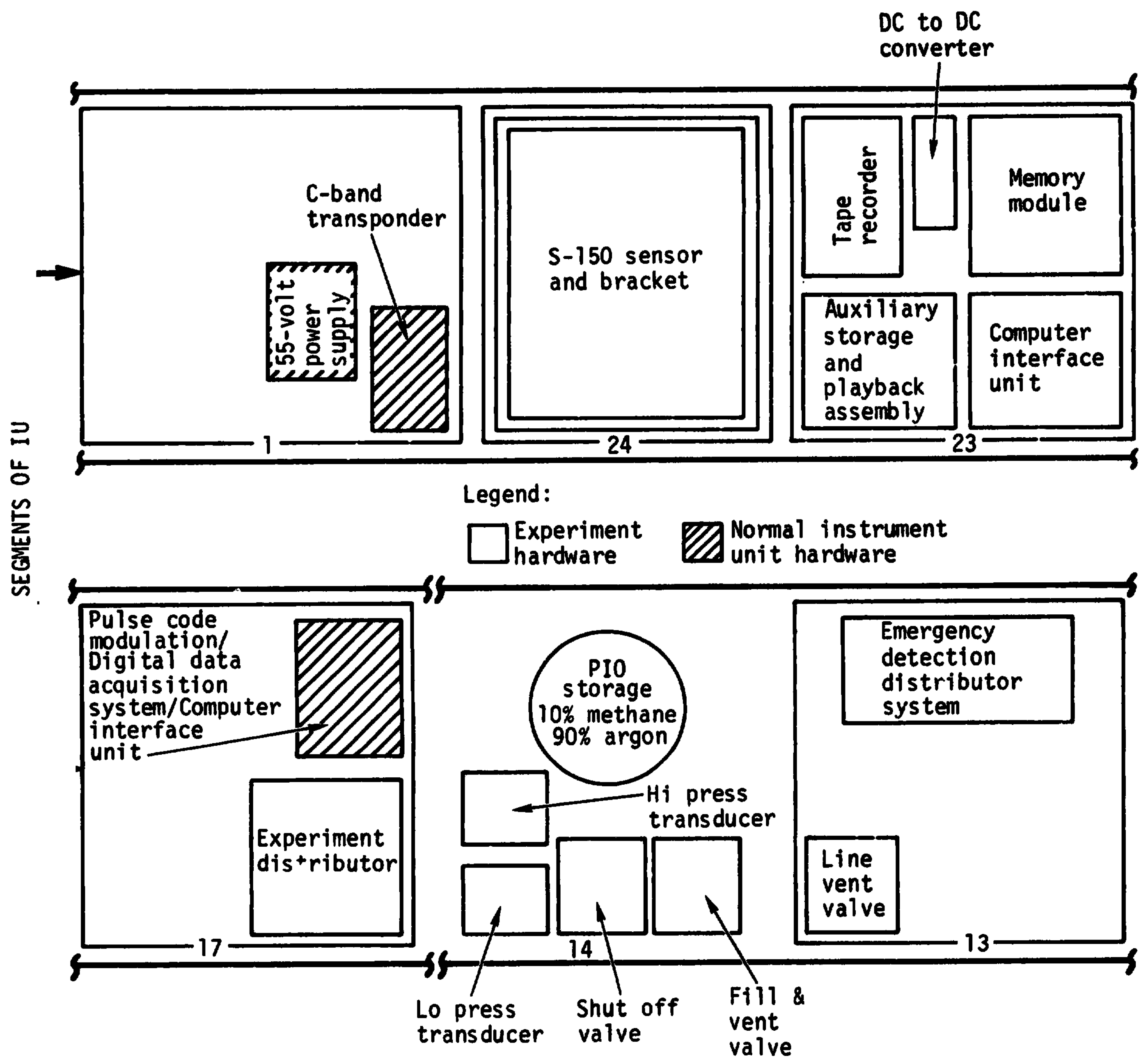

FIGURE III-6. S150 FLIGHT HARDWARE LAYOUT

output was processed by the sensors data processing system for output to the auxiliary storage and playback assembly and/or the IU telemetry system. The experiment sensor contained an analog signal conditioner which conditioned 25 analog housekeeping measurements for presentation to the IU interface. Required internal voltages were developed from the IU supplied +28 VDC power.

Two star sensors (see figure III-5) were provided to supplement the IU launch vehicle digital computer to provide a more accurate X-ray source location in space than could be determined by relying on the IU data alone.

The x-ray counters were pressurized with P-10 gas at about one atmosphere of pressure (14.5 psia). P-10 gas has well-known characteristics as an x-ray counter gas and in the S150 experiment it provided the pressure required to keep the thin x-ray incident window properly positioned against its aluminum mesh support. This window, associated with the counter assembly, was made of "kimfol", an ultra-thin (0.3 mils) polycarbonate material which allows passage of low energy x-rays. The Kimfol window was characteristically leaky and necessitated the use of a constant-density gas system to replace the lost gas.

Mechanical collimators were located over the Kimfol window and gas counters. A smooth aluminum mesh was located between the mechanical collimators and the window material. The mesh provided a smoother surface than the collimators for the window to rest against and provided more surface area support. The mesh was added to help reduce window stress and reduce the probability of increased leakage rate.

(2) Deployment Bracket. The deployment bracket provided mechanical support for the experiment sensor during the prelaunch and liftoff environment and provided a top cover to aid in sensor window protection against contamination. After CSM separation, the assembly deployed the sensor via hydraulic actuators (after pyrotechnic activation) to the 55° viewing position. Switches mounted on the deployment bracket indicated the initiation and completion of deployment. An analog transducer indicated the degree of deployment.

(3) P-10 Gas Panel. A P-10 gas supply system provided the necessary gas for x-ray counter operation during the experiment. The gas supply system was controlled by the P-10 Gas Panel and included a two-cubic-foot sphere, solenoid valves, a pressure regulator and an orifice regulator. The hardware was essentially the same as that used in the IU-ST-124 GN_2 supply system.

(4) Auxiliary Storage and Playback Assembly (ASAP). ASAP was essentially a programmed tape recorder. It recorded experiment sensor and other correlation data for approximately 90 minutes. ASAP recorded data playback by ground command required five minutes over a ground station.

(5) Experiment Distributer. The experiment distributor was basically an IU control distributor. It routed prime power (28 VDC), measurements (analog and digital), measurement power (5 VDC), lines and other experiment controls (e.g., P-10 Gas Panel) to the required components.

2. Experiment Operations. Original plans to survey approximately 87% of the sky during five S-IVB orbits had to be modified for three reasons:

First, a decision was made to de-orbit the S-IVB into the Pacific Ocean after three orbits. (In fact, the last data received in flight was reduced to 2.5 orbits, after experiment turn-on, because of limited ground station coverage.)

Second, a change in mission assignment from SL-4 to SL-3 and the decision to fly the S-IVB vehicle in a retrograde position, would cause the experiment look direction to point directly at the sun, posing the risk of thin window damage. To avoid this, the maneuver program was modified so that the sensor would look below the horizon for 475 seconds following deployment, thus avoiding the sun.

Third, following the SL-1 launch, the S150 launch was again rescheduled to an earlier date, placing the sun in its field-of-view early in the flight. Since the in-flight maneuver program had already been established, a vehicle up-link command to delay the first roll maneuver until 1415 seconds after experiment deployment was necessary to avoid the sun. This maneuver pointed the experiment above the horizon. Limitations in ground station coverage and vehicle command storage prevented evasive maneuvers to avoid the sun during the later orbits.

The Skylab 3 liftoff took place on July 28, 1973 at approximately 11:10 GMT. During vehicle ascent the programmed command sequence vented the unwanted air from the sensor counting chamber. The CSM separated, the detector filled with counting gas, power was applied and the sensor deployed as scheduled. Three tape recorder playbacks were successfully executed. The data received covered 1133:46 GMT to 1243:22 GMT from Texas, 1239:42 GMT to 1412:00 GMT from Goldstone, and 1343:21 GMT to 1516:19 GMT from Honeysuckle.

The S-IVB orbit was as planned and the vehicle guidance system operated successfully throughout the mission. Experiment operations were normal until two hours and ten minutes after launch. X-ray data was gathered from the time the experiment became operational at 30 minutes after launch until this time. At approximately 1313 GMT the experiment look vector passed within 3/4 of a degree of the sun, allowing the sun to be in the field of view of the sensor for up to 13 minutes. This was a longer time than ground tests had indicated

that the Kimfol window could withstand. By approximately 1324 GMT the gas pressure had fallen to 14 psia, below the sensor operating level of 14.5 psia, and no further valid X-ray data could be obtained. The experiment continued to provide star sensor and housekeeping data for the remainder of the time that telemetry was available. At the same point on the following orbit, the experiment look direction again viewed the sun and the supply pressure and counter pressure again decreased (as the gas flow rate through the sensor again increased).

Considerable data was lost from the Goldstone tape playback; apparently due to a weak telemetry signal. This data loss did not affect the primary experiment X-ray data since most of the Goldstone data loss occurred after the loss of operating gas pressure in the sensor.

3. Experiment Constraints. The experiment constraints were successfully met during the mission. The hardware limitation to not view the sun, was not a documented constraint. The PI accepted the risk of limited sun viewing after the first orbit based upon the originally planned launch time.

4. Hardware Performance. The Auxiliary Storage and Playback Unit, the Experiment Distributor and the Deployment Bracket all performed as planned with no malfunctions. The Sensor and Gas Supply System performed well until the sun came within the field of view and caused the proportional counter window to leak too much gas. Due to the increased leak rate, the Gas Supply System did not supply sufficient gas and regulation was lost; thus prematurely ending useful x-ray data. Aside from this anomaly (see paragraph 7) the experiment hardware performed as planned for the duration of the flight.

5. Experiment Interfaces. The experiment interfaces were satisfactorily met during the mission, except for the inability to program maneuvers that would keep the sensor from viewing the sun.

6. Return Data. The magnetic tape data from three ASAP recorder dumps and from two launch vehicle digital computer (LVDC) dumps containing pointing and attitude information was successfully processed and delivered to the PI.

7. Anomalies. At approximately 1313 GMT, the S150 star sensor data and the reconstructed sun angles from launch vehicle digital computer gimbal angle data indicated that the experiment sensor was exposed to direct sunlight. The experiment housing, reference volume and collimater temperatures also began to rise. The sun stayed within the collimator $1.5^{\circ} \times 18^{\circ}$ field-of-view for up to 13 minutes; a longer time than pre-flight tests had indicated the thin polycarbonate window could safely withstand. According to the PI, the chance of this close an approach of the sun to the programmed scan path for random launch time is less than one in ten.

As a result of solar heating, the pressure in the proportional counter tended to increase requiring less gas from the external P-10 gas supply to maintain a constant counter pressure in the experiment sensor. This was indicated by the decreasing frequency of cycling of the control solenoid valve and the simultaneous small upward drift in the supply low pressure reading. This trend continued until about 1318 GMT when the control solenoid valve ceased cycling, indicating the internal counter pressure was such that no gas needed to be supplied, even with a leaking window.

At approximately 1320 GMT the control solenoid suddenly started cycling again at a very high frequency and the supply pressure began to fall at a 5 lb per minute rate. The valve cycling frequency slowed at about 1322 GMT and the rate of decay in the supply pressure decreased as the regulation system attempted to recover. During this time the counter pressure remained constant at its nominal value until the supply pressure differential above the counter pressure reached one psi. The inlet valve to the experiment sensor then went full open and the counter pressure began to decrease. With the decrease in pressure, experiment sensor data was no longer valid. At approximately 1332 GMT the counter pressure dropped slightly below 12 psia and the sensor high voltage was automatically powered down by a built-in pressure transducer. This action prevented the possibility of corona with further pressure decay, as well as completely eliminating any sensor data.

The behavior described above indicates an increased leak rate in the window starting at 1320 GMT which was greater than the P-10 gas supply system could follow and maintain counter pressure of 14.5 psia. The experiment sensor was again exposed to solar radiation at 1540 GMT. Additional counter pressure loss was observed after that time.

Perhaps the most likely physical explanation of the leakage in the experiment window is that the variation in solar heating on the window surface which may have caused deformation of existing holes in the porous material or the creation of new holes.

C. Experiment S183-Ultraviolet Panorama

The Principal Investigator for Experiment S183 is Dr. George Courtes, Laboratoire d'Astronomie Spatiale, Marseille , France. The Hardware Developer was the Centre National d'Etudes Spatiale, Laboratoire d'Astronomie Spatiale, Marseille, France.

1. Experiment Description

a. Objectives. The objective was to obtain the color index of stellar objects in three bands, two are 635 Angstroms (Å) wide centered at 1878Å and 2970Å, and another 360Å wide centered at 2560Å. The stellar objects to be studied were individual hot stars distributed in different regions of the sky in relation to the Milky Way, and collective groups of stars such as clusters, galaxy nuclei, and the stellar clouds in the Milky Way.

The data obtained from this experiment were to be used in the broad sense to determine galactic structure and galactic evolution. Specifically, the ultraviolet (UV) data was to be combined with previously gathered x-ray, visible, infrared and radio spectral data to accomplish this objective. Correlation was to be made with the data of Experiment S019, Ultraviolet Stellar Astronomy, so that comparisons of the spectra and color indices of certain starfields could be accomplished.

b. Concept. The S183 UV Panorama experiment was to photograph specifically selected starfields in the UV spectrum. The optical instrument, or the spectrograph assembly (SA), was to be essentially a wide field-of-view spectrograph which would create two nearly superimposed images of the selected starfield on a single photographic plate. One image was to be centered in a spectral band about 1878Å wavelength and the second image about 2970Å. The exposure durations were to range from 20 seconds to 1260 seconds to allow two-bandpass photography of both bright and dim sources. An operational 16mm data acquisition camera (DAC), attached to the spectrograph, was to simultaneously photograph the starfield being photographed by the spectrograph in a 360Å bandwidth centered around 2560Å. The experiment was to be operated through the anti-solar scientific airlock (SAL) by utilizing the S019 articulated mirror system (AMS).

c. Hardware Description. The experiment equipment consisted of two major assemblies; the SA with accessories, and the film carrousel. The SA (with accessories) was stowed on the support fixture and operated while attached to the S019 AMS. The support fixture was attached to the OWS floor. It formed an airtight seal with the SA front flange, and protected the SA from launch and orbital environments

when the equipment was not mounted in its operational location. The film carrousel was stowed in the film storage container in the OWS film vault and operated in the SA. The hardware is described as follows:

Experiment Hardware	Function
S183 Spectrograph Assembly	This unit (see figures III-7,-8,-9, -10,-11) produced the desired target UV image in the film plate plane and operated the photographing sequence. The unit contained the optics, electronics, and electromechanical parts. Included were: controls for the operating sequence; a finder telescope; a 16mm DAC mount; a 16mm DAC lens; an evacuation valve; and power, control and telemetry connectors. It attached to the S019 AMS and to the support fixture with an airtight fit.
Film Carrousel	This unit (see figure III-12) provided a light-tight casing for 36 photographic plates used in the SA. One or more calibrated plates were included among the thirty-six for control. The unit was attached with a pressure-tight seal to the SA during experiment operation and to the film storage container during launch and storage periods.
Film Storage Container	This unit (see figure III-13) protected the film carrousel when it was not in the SA. The unit was airtight when it contained the film carrousel and had a valve for evacuation.
Film Carrousel Handle	This handle (see figure III-13) was used to attach, remove, and transport the film carrousel to and from the film storage container and the SA. It was attached to the SA when not in use.
Blank Film Door	This door (see figure III-13) was used to seal the opening in the SA for the film carrousel when the film carrousel was not inserted. The

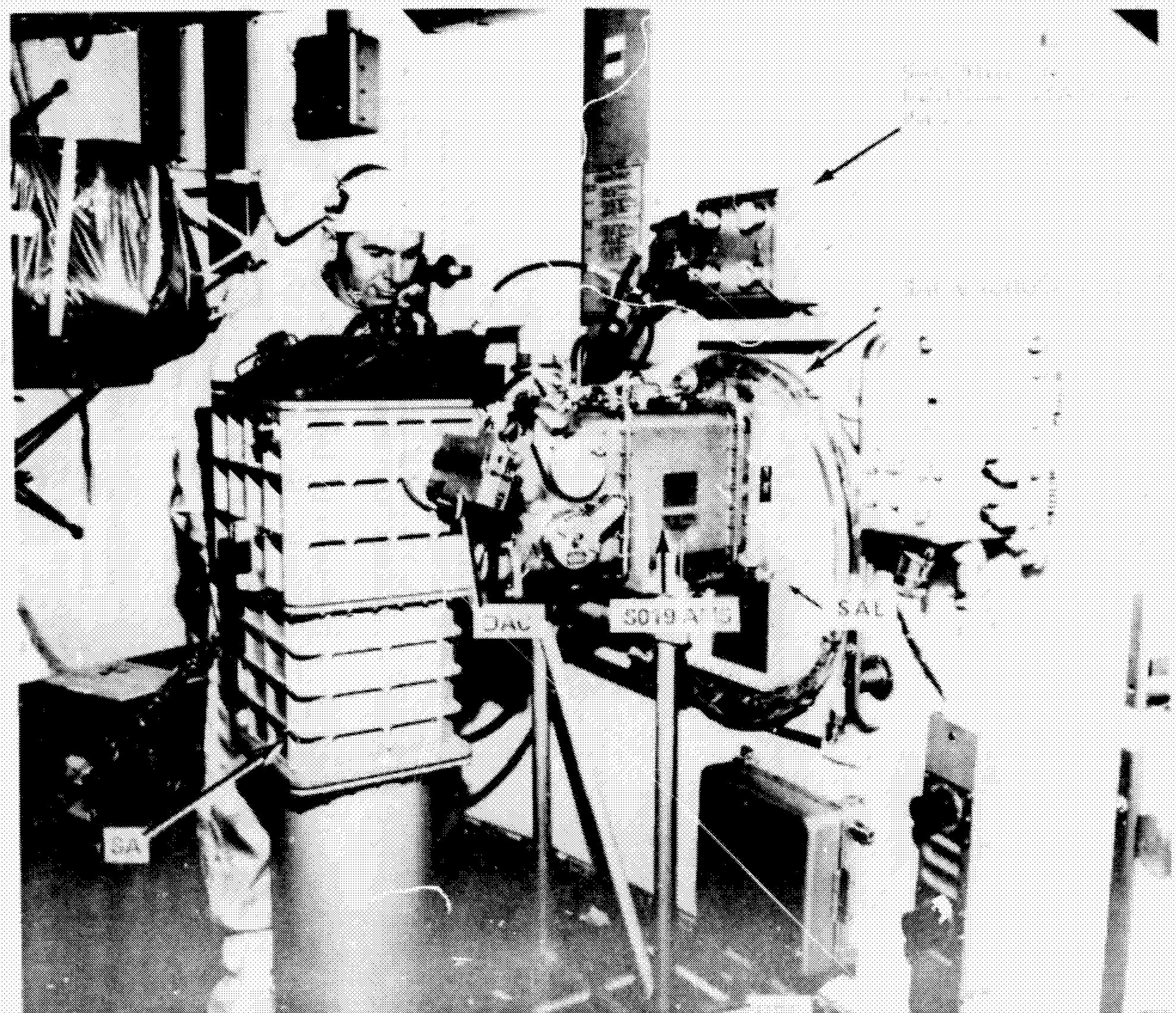

FIGURE III-7. EXPERIMENT S183 MOUNTED TO EXPERIMENT S019 AMS IN SAL

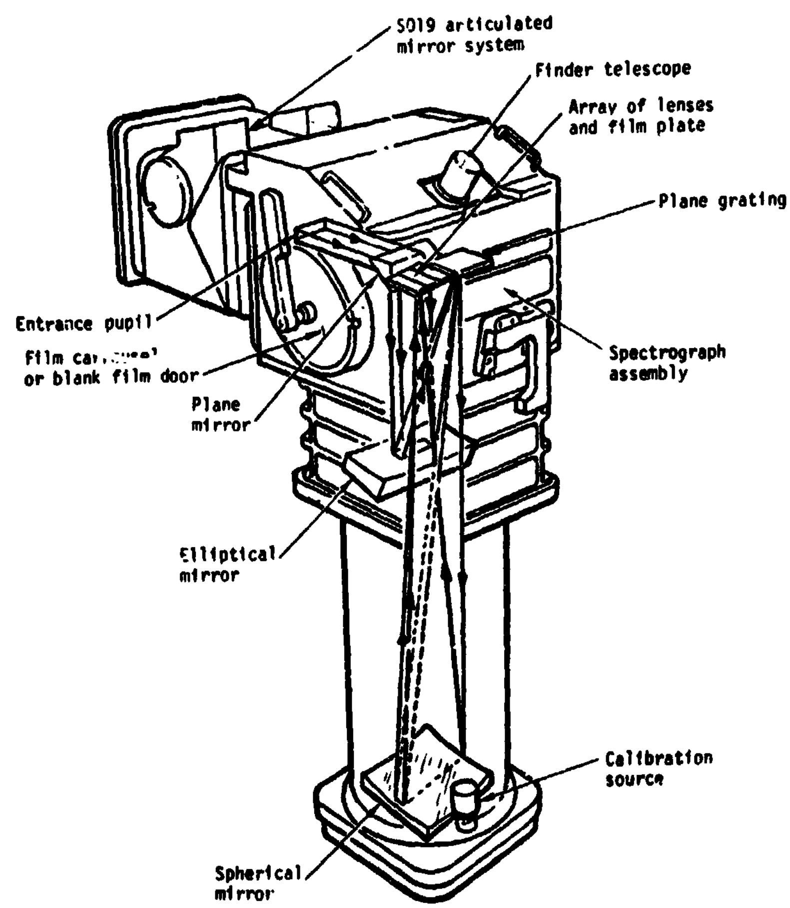

FIGURE III-8. SPECTROGRAPH OPTICS

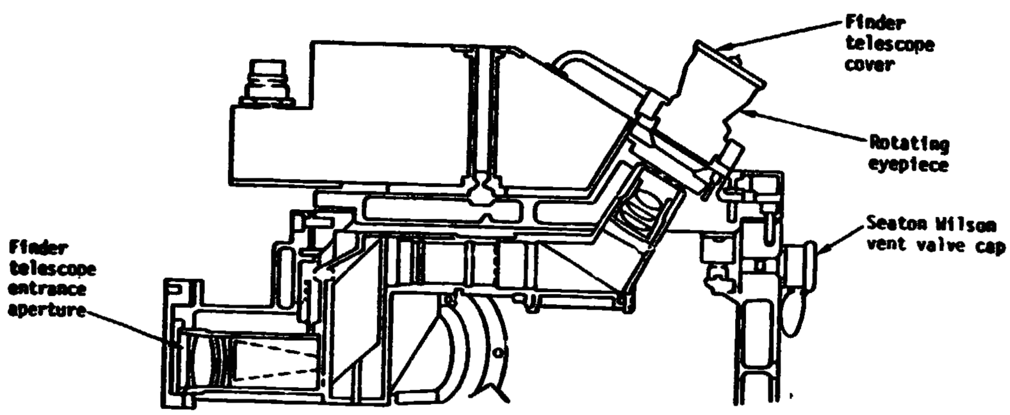

FIGURE III-9. FINDER TELESCOPE

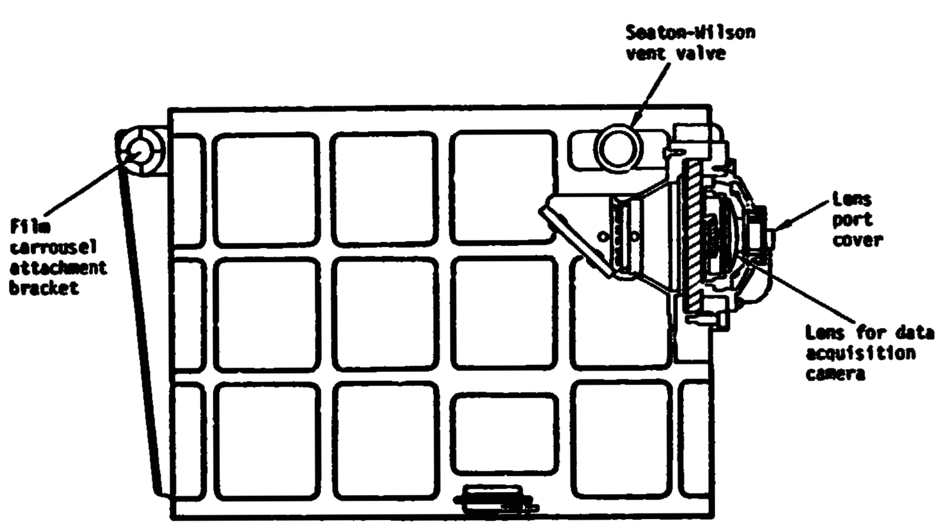

FIGURE III-10. SPECTROGRAPH ASSEMBLY 16mm DAC LENS CONFIGURATION

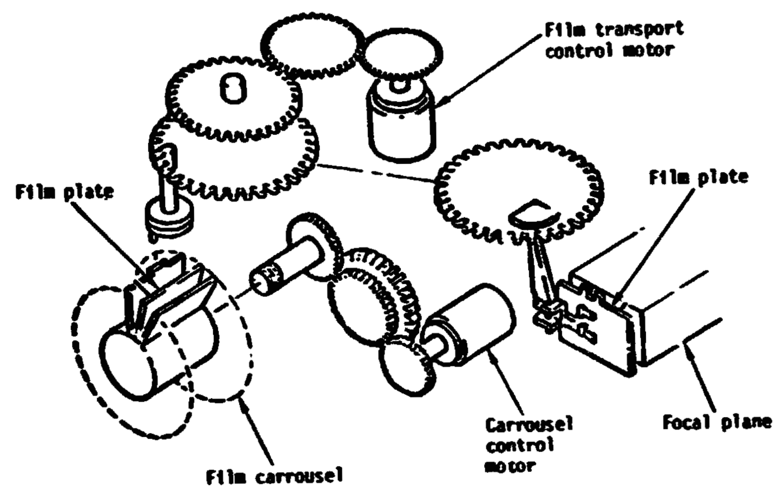

FIGURE III-11. FILM TRANSPORT MECHANISM

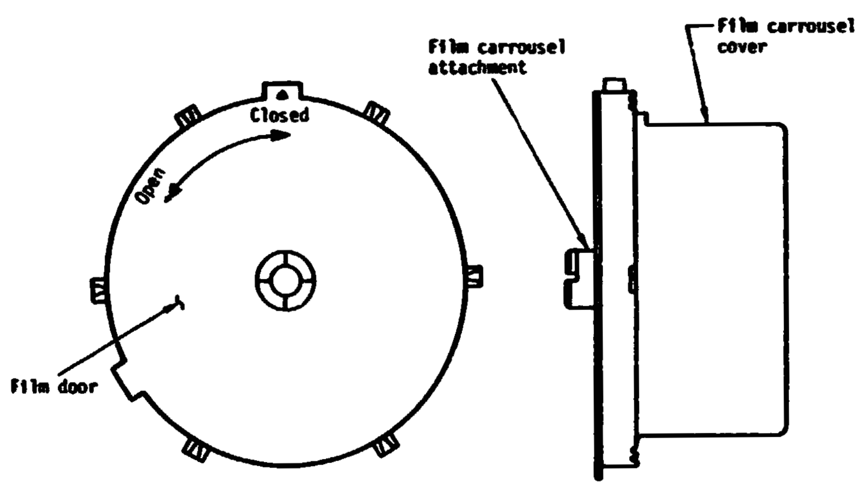

FIGURE III-12. FILM CARROUSEL

Experiment Hardware	Function
Blank Film Door (continued)	seal was airtight. It fit into the film storage container.
S019 Articulated Mirror System	This unit (see figure III-14) provided SA target access and provided controls and displays for pointing the reflective surface to the target. It sealed to the SAL and the SA.
16mm Data Acquisition Camera	This camera, complete with a film magazine which contained 140-ft of 16mm film, provided 16mm exposures on 103aO Kodak UV-sensitive film. Exposures were synchronized for the same durations as the film carrousel plates. Its field-of-view overlapped but was offset by 2.5 degrees from that seen by the SA.

2. Experiment Operations.

a. SL-1/2. One film carrousel (SN 1-1) and one film magazine were launched on SL-1; however, because of concern that the high temperatures experienced due to the meteoroid shield loss may have damaged the film, an additional carrousel (SN 1-2) and an additional film magazine were launched on the SL-2 CM. Thus, two carrousels and two 16mm film magazines were available for use on SL-2.

Experiment operations on SL-1/2 began on DOY 153, carrousel 1-2 was installed and three exposures were successfully completed. On DOY 154, two exposures were accomplished and a malfunction of the SA occurred. A malfunction procedure was sent to the crew which cleared the unit for further operations and carrousel 1-2 was stowed for return. On DOY 155, the unit took photographs with the DAC only. Carrousel 1-1 was installed in the spectrograph on DOY 170 and seven exposures were accomplished. A photographic data summary is presented in table III-1.

The crew discovered that the night side of the orbit was not dark for as long as the schedule stated. This required the exposures to be started approximately one minute later and terminated approximately one minute earlier to prevent reflected sunlight from entering the instrument. The planning was adjusted to accommodate the shorter night cycle and experiment operations were changed accordingly.

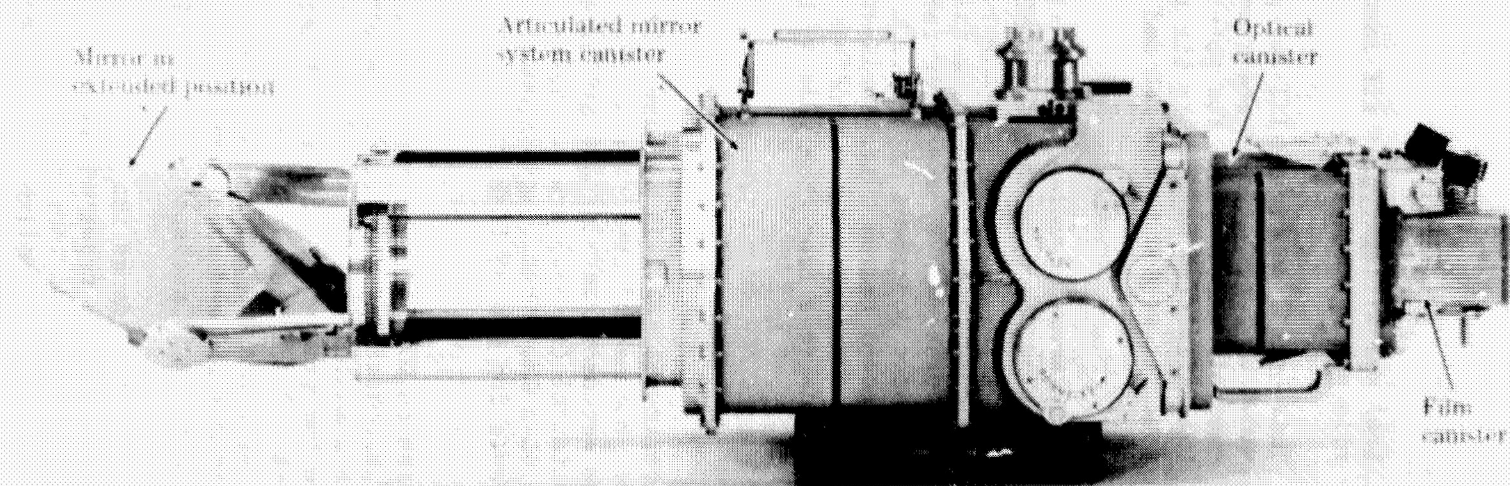

FIGURE III-14. S019 SHOWING ARTICULATED MIRROR SYSTEM

TABLE III-1 SL-2 STARFIELDS

Carrousel (SN)	GMT Start Time (DOY HR MIN)	Plate Number	Starfield Designator	Exposure (Seconds)	Right Ascension HR:MIN	Declination DEG:MIN
1-2	153 1732	3,4	303	160, 1260	0600	-71:40
		5	223	620	1334	57:00
	154 1344	6,7	252	160, 1260	1035	-62:00
(DAC Only)		8 (See Note 1)	301	620	--	--
(DAC Only)	155 1303		253	300	1134	-61:44
(DAC Only)	155 1314		292	300	2040	41:10
1-1	170 1752	5	155	160	1210	-65:10
	170 1824	6	218	940	1217	09:20
	170 2301	8,9	249	20, 300	1127	-66:20
	170 2310	10,11	55	20, 300	1248	-62:49
	170	12	289	20	2118	31:40

NOTES:

1. No exposure was obtained on plate number 8 due to a malfunction
2. Total Exposures obtained were:
   Carrousel 1-2 5 plates from carrousel simultaneously with 5 DAC frames
   Carrousel 1-1 7 plates from carrousel simultaneously with 7 DAC frames
   DAC only 3 frames

b. SL-3. Unresolved SL-1/SL-2 film fogging problems (see paragraph 7.a.), necessitated operating the SA using only the DAC during the SL-3 mission. The operations are listed in table III-2.

Additional data was obtained for S183 by utilizing the S019 UV Stellar Astronomy experiment and film to obtain S183 target photographs. The operations are listed in table III-3.

On DOY 240, the S019 equipment was used to expose eleven frames of seven separate starfields. On DOY 243, the S183 equipment was used to expose three frames of starfield SSC the last two of which should have been of the starfield PLD. On DOY's 246, 248 and 249, S019 film canister (SN-003) frames 128 thru 143 were used. Frame 139 mirror setting was in error by 10 degrees in rotation giving a 10 degree error in declination for starfield N7. Frame 140 exposure was started 12 minutes late due to lack of setup time. The next exposure on DOY 141 of starfield SMC was stopped early due to sunrise.

The S183 DAC operations were started again on DOY 255 obtaining two exposures. On DOY 260, one exposure each was obtained for starfields CHI(h and XPER) and CMG (LMC). On DOY 261, one exposure each was obtained for starfields OAB (PER) and PMC (SMC). The PMC (AMC) starfield exposure was terminated early to avoid sunrise. Three exposures were made on DOY 262 of an unknown field and M57 and M42. The unknown field exposure was due to an error in the mirror rotation setting. The last M42 exposure was terminated early due to sunrise.

TABLE III-2 SL-3 S183 DAC PHOTOGRAPHS

Frame	GMT Start Time DOY HR MIN	Exposure (Seconds)		Starfield Designator	Right Ascension HR:MIN	Declination DEG:MIN
		Pad	Verified			
1	243 0106	300	(See Note 3)	SSC	18:35	-18:00
2	243	160	(See Note 3)	SSC (See Note 4)	18:35	-18:00
3	243	1260	(See Note 3)	SSC (See Note 4)	18:35	-18:00
4	255 1429	300	300M	PER (OB3)	3:27	53:00
5	255 1437	1260	1270M	PLD (M45)	3:56	28:00
6	260 1848	300	300M	CHI (h and XPER)	2:00	61:30
7	260 1858	1260	1220M	GMC (LMC)	5:35	-74:10
8	261 1155	300	-----	OAB IPER)	21:25	58:10
9	261 1202	1260	1208T	PMC (SMC)	23:38	-74:35
10	262 1728		20M	Unknown (See Note 5)	-----	-----
11	262 1730	620	660M	M57	19:04	28:40
12	262 1744	940	640M	M42	5:50	- 8:20

NOTES

1. Symbol "M" following the exposure time indicates that the exposure duration was confirmed by MOPS data to ± 10 seconds.
2. Symbol "T" following the exposure time indicates that the exposure time was verified on voice tape.
3. The tape recorder was not turned on for this pass.
4. Exposures on frames 2 and 3 should have been of field PLD. Field SSC was not available during the whole 1260 second exposure.
5. Exposure was obtained of an unknown field due to error in mirror rotation setting. Exposure was terminated early and mirror reset.

TABLE III-3 SL-3 S019 PHOTOGRAPHS FOR S183
(S019 Film Canister SN-003)

Frame	GMT Start Time DOY HR:MIN:SEC	Exposure (Seconds)	Starfield Designator	Right Ascension HR:MIN	Declination DEG:MIN
55	240 14:03:29	90U	080 SSC	18:10:47	-21:04
56	14:05:13	600U	080	18:10:47	-21:04
57	14:16:11	30U	013 PLD	03:44:31	23:57
58	14:16:52	600U	013	03:44:31	23:57
59	14:28:12	241U	101 LMC	05:35:00	-68:50
60	18:43:35	226	L2	16:32	-28:07
61	18:47:41	29	L2	16:32	-28:07
62	18:48:57	226	CL4	18:15	-18:38
63	18:53:26	227	CL5	21:01	59:47
64	18:57:49	720U	N35	23:05	61:27
65	19:11:30	78	L2	16:32	-28:07
128	246 19:11:28	899U	107 PLD	03:47	23:54
129	19:27:41	960U	LMC	05:39	-69:06
130	248 00:42:11	272U	L-3	21:59	62:15
131	00:47:25	598U	HYD-1	04:25:48	15:46
132	00:57:57	270U	L-1	16:43	-58:15
133	01:03:00	719U	CLN	03:55:43	35:39

TABLE III-3 (Continued)

Frame	GMT Start Time DOY HR:MIN:SEC	Exposure (Seconds)	Starfield Designator	Right Ascension HR:MIN	Declination DEG:MIN
134	248 02:15:15	960U (See Note 1)	N3	20:47	67:58
135	Not Available	960U (See Note 1)	N4	2:47	60:13
136	13:09:18	960U	M7C	17:51	-34:48
137	13:26:17	948U	M8A	18:02	-24:20
138	14:41:08	956U	N9	18:52	32:58
139	14:58:20	960U	N7	04:20	-26:00 (See Note 2)
140	21:06:09	960U	N6 (See Note 3)	18:15	-16:00
141	21:24:02	209U	SMC (See Note 4)	00:55	-74:30
142	249 00:53:10	973U	N8	00:02	72:15
143	01:10:01	900U	SMC	00:55	-74:30

NOTES

1. No voice confirmation of exposure times on frames 134 and 135.
2. Correct mirror rotation was to be 101 degrees for this field, however astronaut error resulted in an actual mirror rotation of 111 degrees which caused an approximate 10 degree error in declination to -26 degrees.
3. Exposure started 12 minutes late due to lack of set-up time in the no - EREP alternate flight plan. The earth may have occulted part of the time.
4. SMC exposure stopped early due to lack of time before sunrise.
5. U - Unwidened exposure (i.e., the spectral widening feature provided by S019 was not used).

c. SL-4. One film magazine and two film carrousels with a total of 72 photographic plates were launched on SL-4. One carrousel (SN 2-2) contained 36 plates of 101-05 film type. One carrousel (SN 1-1) contained 101-06, SC-5, 103aO, and 101-05 film types. The SA was operated to expose 43 frames, 11 from carrousel 1-1 and 32 from carrousel 2-2. However, post-mission film development indicated that due to mechanical failure, only plate 19 in carrousel 1-1 had actually been exposed. The exposure details are shown in tables III-4 and III-5.

The DAC was mounted on the SA to simultaneously photograph the starfield being photographed by the SA. 35 DAC exposures were obtained, however, 11 showed evidence of fogging from light leaks. The SA replacement optics used by the DAC were installed to solve the focus problems encountered on SL-2 and SL-3 (see paragraphs 4 and 7).

On DOY 333, two exposures from carrousel 2-2 were planned, for 1260 seconds and 300 seconds duration. Due to an unexplained spectrograph operation anomaly, a 20-second exposure occurred just before the 1260 second exposure. The 1260 second exposure was terminated at 1080 seconds due to sunrise. During removal of carrousel 2-2 the astronaut reported a film plate protruding from the carrousel.

On DOY 334, two carrousel 1-1 plates were exposed, but an anomaly was reported when the carrousel was removed from the SA. The CDR reported a piece of film plate glass was holding the carrousel film gate open.

On DOY 339, carrousel 2-2 was synchronized, to correct the misalignment incurred from the anomaly on DOY 334. The alignment was apparently successful. Carrousel 2-2 was used on DOYs 340 and 341 for eight exposures, which were accomplished except that four were cut short due to sunrise. While removing the carrousel from the SA, another anomaly occurred which misaligned the carrousel.

On DOY 345, an alignment procedure was accomplished to properly index carrousel 1-1. On DOYs 347 and 348, plates 13 and 14 were exposed in carrousel 1-1 instead of the planned frames 21 and 22 because the SA was not reset after its last use. Another piece of glass was found upon retracting carrousel 1-1 from the spectrograph.

On DOY 352, carrousel 2-2 was synchronized and four exposures completed. The SA was operated on DOY 365 with carrousel 2-2 for four exposures.

TABLE III-4 SL-4 CARROUSEL 1-1 PLATE EXPOSURES

Plate	GMT Start Time (DOY)	(HR MIN SEC)	Exposure (Seconds)	Starfield Designator	Rotation	Tilt	Right Ascension	Declination
00	Note 3		Note 3		-	-		
01								
02								
03								
04								
05								
06								
07								
08								
09								
10								
11								
12								
13	347	21 01 21±1	1160	97A	40.9	23.7	-----	-----
14	348	00 23 20±1	240	COMET	195.8	25.0	-----	-----
15	003	15 42 08±1	160	COMET	253.1	20.3	20:19	-17:00
16								
17								
18	Note 3		Note 3					
19	334	23 39 57±3	1260	129 (C45)	183.9	0.4	08:31	15:10
20	335	00 03 03±3	180	130 (C47)	193.3	5.1	08:44	06:36
21	003	15 48 49±1	1260	C35	104.6	1.6	-----	-----
22	003	21 56 17±5	1260	C11	307.6	1.7	03:31	49:10
23	003	22 20 17±5	300	C49	154.7	7.5	09:46	-47:00
24	029	12 08 16±1	620	52B	263.9	16.3	-----	-----

Continued on next page

TABLE III-4 (Continued)

Plate	GMT Start Time (DOY)	(HR MIN SEC)	Exposure (Seconds)	Starfield Designator	Rotation	Tilt	Right Ascension	Declination
25	029	12 20 57±1	620	CEN	235.2	31.2	-----	-----
26	029	12 33 19±1	380	M53	172.6	2.8	-----	-----
27								
28	Note 3		Note 3		-	-		
29	Note 3		Note 3		-	-		
30								
31								
32								
33								
34								
35								

NOTES:

1. Film emulsion for each plate was as follows:

   Plates 00 thru 18 = 103a0
   Plates 19 thru 28 = 101-05
   Plates 29 thru 34 = SC-5
   Plate 35 = 101-06

2. Exposure durations for plate 20 was obtained from interpretation of crew voice transcriptions. All other times were obtained from MOPS data to the accuracy as indicated.

3. Plates 00, 18, 28, and 29 were exposed pre-flight to JSC sensitometry.

4. DOY 334 thru 365 are year 1973. DOY 001 thru 039 are year 1974.

5. Lack of entires in the table for a particular plate indicates that no exposure utilizing that plate was attempted.

TABLE III-5 SL-4 CARROUSEL 2-2 PLATE EXPOSURES

Plate	GMT Start Time (DOY)	(HR MIN SEC)	Exposure (Seconds)	Starfield Designator	Rotation	Tilt	Right Ascension	Declination
00	Note 3		Note 3		-	-		
01	340	14 45 24±3	1260	CM3	325.4	12.1	01:10	-26:55
02	340	15 09 47±3	270	C39	246.0	21.0	07:47:42	-46:14:46
03	340	19 25 03±3	620	C29	253.2	0.4	06:20	-32:55
04	340	19 38 45±3	1160	CM8	119.0	7.8	10:44	67:55
05	340	22 31 03±3	940	CM1	318.6	25.7	00:38	-40:00
06	340	22 49 27±3	876	C40	243.7	4.0	08:08	-47:11:17
07	341	01 55	300	C13	45.2	18.3	03:44:30	23:57:07
08	341	02 07	300	COMET	45.2	18.3	14:19:06	-22:36:27
09	028	22 09 48±1	1260	C14	35.5	3.8	-----	-----
10	011	22 41	720	COMET	258.9	20.4	21:57:00	-09:20:00
11	011	22 55 43±1	550	C55	155.3	25.5	12:30:00	-61:40:00
12	028	22 34 31±1	340	CM3	162.4	8.1	-----	-----
13	352	15 49 39±3	1260	C99A	16.2	9.6	23:27	56:12
14	352	16 13 21±3	300	C38A	NA	NA	07:16	-38:41
15	352	22 02 04±1	1260	C24	40.8	3.3	-----	-----
16	352	22 32 09±1	160	COMET	205.6	21.2	-----	-----
17	365	16 13 21±3	620	001	320.3	17.7	00:46	55:50
18	365	16 26 21±3	1240	122	75.7	14.7	12:51	12:50
19	365	17 46 15±3	1260	119	NA	NA	12:46	30:10
20	365	18 09 57±3	620	043	NA	NA	08:20	-50:25
21	004	15 02 17±1	1260	05A	298.2	16.4	00:48	39:45
22	004	15 25 41±1	300	C42	159.9	3.7	07:52	-40:06:30
23	005	19 00 00±1	1260	05B	296.8	13.8	01:06:22	40:40:22
24	005	19 24 04±1	300	C50	155.1	27.0	09:04	-61:10:00

Continued on next page

TABLE III-5 (Continued)

Plate	GMT Start Time (DOY)	(HR MIN SEC)	Exposure (Seconds)	Starfield Designator	Rotation	Tilt	Right Ascension	Declination
25	010	00 03 36±1	300	COMET	255.3	19.1	21:35:00	-11:30:00
26	010	00 11 37±1	1040	C52	149.2	24.3	11:25:29	-60:09:35
27	014	00 32 31±1	810	C06	298.4	16.7	-----	-----
28	029	01 15 28±1	620	CM4	5.7	28.3	-----	-----
29	029	01 28 11±1	620	C46	276.7	12.0	-----	-----
30	029	01 41 12±1	340	C7	68.2	18.9	-----	-----
31								
32								
33								
34	333	22 55 35±1	20	129 (C45)	185.5	00.1	08:31	15:10
35	333	22 56 56±30	1040	129 (C45)	185.5	00.1	08:31	15:10

NOTES:
1. Film emulsion for all plates contained in carrousel 2-2 was 101-05 type.
2. Start times or exposure durations for plates 07, 08, 10, 11, and 26 were obtained from interpretation of crew voice transcriptions. All other times were obtained from MOPS data to the accuracy as indicated.
3. Plates 00 and 35 were exposed preflight to JSC sensitometry.
4. DOY 333 thru 365 are year 1973. DOY 001 thru 039 are year 1974.
5. NA = Data not available.
6. Lack of entries in the table for a particular plate indicates that no exposure utilizing that plate was attempted.

On DOY 003 four exposures were made in carrousel 1-1. The crew commented that, during carrousel 1-1 synchronizing the "E" clip used to load the carrousel detent mechanism had broken and the spring had come out. A malfunction procedure was attempted on carrousel 1-1 to retract plate 29, but failed.

Two frames of carrousel 2-2 were exposed on each of DOY's 004, 005, 010, and 011 and one on DOY 014.

On DOY 021, the crew reported an SA electrical malfunction, rendering the unit inoperative. A repair procedure was successfully performed on DOY 027. However the DAC cable could not be connected to the SA, eliminating any possible automatic operation with the DAC. This was not a significant loss as the only S183 DAC film magazine on board was jammed and no other ultraviolet sensitive 16mm film was available.

On DOY 025, two exposures were made using the S019 experiment hardware (see table III-6).

On DOY 028, with the electrical problem solved for the S183 SA, carrousel 2-2 was installed and two exposures were made. Operations continued on carrousel 2-2 into DOY 029 when three frames were exposed. On DOY 029, carrousel 1-1 was installed and three exposures were made. There were no S183 operations after DOY 029.

3. Constraints. The experiment constraints were successfully met during the mission except:

a. The requirement to avoid S183 operation in bright moonlight (moon more than half illuminated) was waived after consultation with the PI. In fact, pictures were taken on SL-2, DOY 170, four days after a full moon because of the anti-solar SAL availability. The DAC 103a0 pictures taken on DOY 170 show scattered light from contaminant particles in the field-of-view. This did not obscure stars nor fog the film as originally feared, but did create the minor problem of distinguishing the stars from the contaminant particles. In one instance, the S183 pass was postponed when the ATM star-tracker followed a contaminant particle instead of a star.

b. The target pointing requirement within one-half degree was not met. Photograph analysis, in some instances, showed the error was as much as two degrees. Factors which may have contributed to pointing inaccuracies were: crew motion, thruster attitude control subsystem firings, unscheduled venting, thermal bending of the vehicles, inaccuracies in the mirror tile or rotation control and inaccuracies in NuZ calculation or misinterpretation and the resultant rotation calculation utilizing the NuZ.

TABLE III-6 SL-4 S019 PHOTOGRAPHS FOR S183
(S019 Film Canister SN-002)

Frame	GMT Start Time (DOY)	(HR MIN SEC)	Exposure (Seconds)	Field
108	025	01 07 58	1021	CVC
112	025	13 36 02	900	M54

NOTE:

1. Both frames were exposed with prism in, unwidened.

2. Start time and exposure duration were obtained from crew voice transcriptions.

NOTE: NuZ was ground calculated and included on the uplinked PAD with the ground calculated tilt and rotation control settings for the target starfield. The crew checked the NuZ, utilizing on-board readouts, and if this value differed from the PAD by more than 0.5 degree, the crew made a calculation to correct the PAD rotation setting.

c. The requirement to use two crewmen for experiment setup and stowage due to the SA mass was eliminated after the SL-2 crewmen demonstrated (on TV) the ease with which it could be transferred and installed in the SAL and its stowage pallet.

d. During the SL-4 operation it became evident that the crew was having problems completing exposures before sunrise. The PADs contained adequate time for the requested exposures, including approximately one minute for the instrument to move the slide into position before the exposure time began. However, it was sometimes necessary to terminate the exposures approximately one minute early when exactly enough time for the exposure was allowed prior to sunrise.

4. Hardware Performance

a. SL-1/2. The hardware performed as planned with six exceptions.

The film plate holder which jammed in the SA (see paragraph 7.a).

A focusing problem with the DAC was discovered after the SL-2 mission film was developed. Some star images appeared as small circles, rather than point sources. This problem investigation was continued during SL-3 and was resolved on SL-4 (see paragraph 4.c).

An anomalous exposure sequence occurred with the DAC (see paragraph 7.a).

Three DAC frames partially fogged due to light leakage. This was caused by the shutter not closing to a light tight condition.

Light leaks also caused partial fogging on four DAC frames. The light leaks occurred when the exposure was terminated prematurely by setting the sequence switch to STANDBY. The DAC shutter was not designed to close on the STANDBY switch setting.

The sixth exception was SC-5 film emulsion degradation on plates contained in the carrousels. Film from both the carrousels exhibited a sensitivity loss and had image fade. The problem cause has never been adequately explained.

b. SL-3. The SA operated as scheduled without exception. Operating problems were minimized because no film carrousels were used during this mission, due to unresolved problems with film degradation within the carrousel units.

Photographs from the DAC film returned from SL-1/2 had evidenced defocusing, the star images resembled smoke rings rather than points of light. The SL-3 crew used different cameras on the spectrograph to drive the 16mm magazine to test the theory that the camera was causing the defocused star images. However, the SL-3 film showed similar imagery which proved that the problem was on the SA side of the interface. The DAC optics section of the SA was replaced on SL-4. (See paragraph 4.c.) DAC film fogging due to light leaks similar to the SL-1/2 exposures occurred on SL-3 (see paragraph 4.a).

c. SL-4. The DAC optics section of the SA was replaced with the backup unit optics on DOY 329. This Schmidt cassegrain telescope section was installed by the crew. The tools and replacement optics were supplied on the SL-4 launch. The optics replacement successfully solved the focus problems encountered on SL-2 and SL-3. Both optics were returned to earth for test.

The SA and DAC were operated simultaneously until DOY 21, when the DAC film magazine (UA04) jammed.

Carrousel 1-1 operational usage was plagued by broken glass from SC-5 film plates which, apparently, were in or near carrousel position 33. The cause of breakage could not be determined, but the glass fragments resulted in incidents of jamming the film carrousel slide door open and incidents of jamming the carrousel so that it would not rotate to the correct slide for removal. Slide 00 was the only carrousel slide without a tab to pull it from the carrousel. The carrousel drive mechanism incorporated a safety feature which would enable the drive mechanism clutch to slip if carrousel friction forces were too high preventing damage to the motor. Unfortunately, the slide number indicator was not linked to the carrousel directly and the indicator advanced even though the carrousel did not move. This feature left the carrousel indexed to the wrong position for removal, and caused a slide to be partially removed from the carrousel upon retraction from the SA.

Carrousel 2-2 problems were caused by not indexing the SA counter to 01 before carrousel insertion or retraction. The problem was common to carrousel 1-1. The error would cause the wrong film plate to be exposed and carrousel film plates to be pulled upon the carrousel's extraction from the SA. The first improper indexing resulted from SL-3 operations without a carrousel. Since only the DAC was used on SL-3, the carrousel indications were ignored. SL-4 operations incorrectly presumed that the SA had been returned to position 01 after the last SL-3 operation. There was never any broken glass associated with carrousel 2-2.

The SA made two known unprogrammed exposures. The first, on DOY 333, was a 20-second exposure just prior to a 1260-second planned exposure. This anomaly coupled with another anomaly on the same day related to the incorrect spectrograph frame indication prior to starting operations. It is not evident that the two problems were related. The second unprogrammed exposure occurred when the SA drive mechanism advanced one position from frame 12 to frame 13 before starting an exposure on DOY 352. This created no problem since all the film within carrousel 2-2 was the same type and no double exposures occurred. At all other times, the operation was per design and the mechanism would advance only to the frame indicated before the exposure.

The blown fuse within the SA on DOY 021 was apparently caused by the DAC film jamming the drive mechanism. The DAC internal fuse accommodated the DAC normal starting power which was a surge of approximately 2.3 amperes maximum, decaying to a normal run current of 0.5 ampere in 70 milliseconds. DAC power was supplied via the SA. This circuit was protected by a two ampere fuse in the SA with the same rating as the DAC fuse. The SA fuse, in addition, supplied power to the SA's internal electronic circuitry. It was thought that (when the film jammed in the DAC) the resulting prolonged current surge overloaded both fuses, however, the SA fuse blew first since it carried the greater load i.e., both DAC and Spectrograph electronics current. The SA operation was returned to normal, without the DAC by building a jumper cable from voltmeter test leads available from a kit aboard Skylab.

Procedural problems were limited to improperly setting the SA frame counter index readout before film carrousel installation or removal. The resultant misaligned carrousels had to be manually repositioned to the correct frame number to permit proper installation. The unit required a slide without an index tab to facilitate insertion and extraction and the only slide in the carrousel meeting that requirement was in the 00 position.

An E clip was broken on carrousel 1-1. This clip was used to retain a spring which forced the carrousel into indexing detents and assured a positive lock. This did not eliminate operation with this carrousel. However, it made it difficult to ensure proper installation.

DAC film fogging due to light leaks identical to the SL-1/2 and SL-3 experiences occurred on SL-4. (See paragraph 4.a.)

Post-mission development of the photographic plates revealed that most of the exposures contained no data. Only plate 19 in carrousel 1-1 had actually been exposed. This indicated that the carrousel had been desynchronized in the early part of the mission and, therefore, no exposures could be taken. It was speculated, that the broken glass could have led to this mechanical failure.

5. Interfaces. The experiment interfaces performed satisfactorily during the mission except the OWS film vault temperature. This temperature reached a computed maximum of 51°C (125°F) and was in excess of 38°C (100°F) for 13 days early in the mission. Although this temperature was in excess of the anticipated maximum of 32°C (90°F), it has been discounted as a primary factor in the SC-5 film degradation in carrousel 1-1.

6. Return Data. SL-1/2 return data consisted of: two film carrousel containers; one 16mm film magazine containing 15 exposures for S183; and, carrousel 1-2 ejected plate 08.

SL-3 return data consisted of one 16mm film magazine containing 12 exposures for S183 and 27 S019 exposures of S183 starfield targets.

SL-4 return data consisted of: one 16mm film magazine containing 35 exposures for S183; two film carrousels; both SA optic sections; and, two S019 exposures of S183 starfields.

7. Anomalies.

a. SL-1/2. A carrousel 1-2 film plateholder was jammed in the SA on DOY 154. Initially it was believed that the sequence switch had been operated before the sequence was complete. The crew performed the on-board malfunction procedures unsuccessfully. New malfunction procedures requested the crewman to remove the film carrousel, reach into the SA and remove the film plate with his fingers. When this was unsuccessful, the power was applied and the SA ejected the film plate. Power was applied briefly. Although the SA motors were not qualification tested for operation in an oxygen atmosphere, no damage resulted. On subsequent SL-1/2 operations no further problems were reported with either carrousel. Post-mission inspection showed that the film plate holder was within specification and there is currently no explanation for this problem.

The DAC shutter got out-of-phase with the SA shutter when the SA sequence switch was cycled to STANDBY to end an exposure sequence. When this happened the DAC shutter was left open and remained 180 degrees out-of-phase with the SA shutter. Thus, the DAC shutter was open when the SA was moving film plates to and from the film carrousel and the shutter was closed when the SA was exposing a film plate. This resulted in the loss of many of the DAC frames, in fact, only 4 out of the 15 exposed proved to be useful.

An additional film carrousel was launched on SL-2 since it was assumed the high OWS film vault temperature had damaged the carrousel film which was launched in the OWS film vault. Film for both carrousels showed latent image degradation. Since both film carrousel's contents were degraded, post SL-1/2 film plate tests were performed by the French experimenters and MSFC. The problem could not be reporduced, indicating that the high temperature, alone, was not responsible.

Post-mission evaluation of the DAC photographs revealed a focusing problem which was further investigated during SL-3 (see paragraph 4.b.) and resolved on SL-4 (see paragraph 4.c.).

Partial fogging of DAC photographs was a common problem on all missions. Fogging occurred due to light leakage from the shutter not closing to a complete light tight configuration or continuing the exposure into the daytime part of the orbit. This occurred when the film carrousel exposure was terminated prematurely by setting the switch to STANDBY. The DAC shutter was not closed on a STANDBY switch setting.

b. SL-3. The film emulsion type was changed from SC-5 to 101-05 to make plates available for SL-3. These plates fogged after a short period in the carrousels before launch. Within days before launch, new 101-05 film was loaded in the carrousels but completely fogged within 72 hours. Hence, no film carrousels were launched on SL-3. Subsequent testing indicated that a major cause of the fogging was probably outgassing of some chemical product used in the Delrin film holders' gold-coating process. The French manufactured silver-coated Delrin holders for SL-4 launch.

Partial fogging due to light leaks occurred as on SL-1/2 (see paragraph 7.a.).

The SL-3 DAC photograph post-flight evaluation revealed the same defocusing experienced in SL-1/2 data. Hence the SA optics for the DAC required replacing during SL-4, before S183 SA operations.

c. SL-4. Several problems occurred, many of them interrelated. They are in chronological order below.

Due to S183 operation during SL-3 without a carrousel, the SL-3 crew had left the unit in the 04 position, as indicated on the panel display, without resetting it to an 01 indication as normally required per the checklist when operating with a carrousel. Therefore, when carrousel 2-2 was installed on DOY 333, the 01 slide was indicated as slide 04 by the unit. The crew then selected plate 01 (per PAD) for exposure, but due to the three-plate offset error they actually selected and exposed plate 34. However, for unexplained reasons the spectrograph jumped ahead to plate 35, after 34 was exposed for approximately 20 seconds instead of exposing for the planned 1260 seconds. Plate 35 a control plate with preflight sensitometry data, was then exposed for the balance of the exposure. This was verified via telemetry. The second planned 300-second exposure was not performed for lack of time.

Per procedure, the carrousel was then advanced to the 01 indicated position for removal. This normally would have placed plate 00 in the carrousel film gate. Upon removal, the crew reported that a slide was protruding from the carrousel and that it was pushed in without identifying the slide by number. Assuming the information on the three-plate offset was correct, then plate 33 was the plate that had projected from the carrousel. If plate 00 had been in the film gate, it would not have been removed from the carrousel. Plate 00, by design, lacked the index tab that the other plates had for pulling by the SA film transport mechanism.

The second SA operation during SL-4 was to expose carrousel 1-1 plates 19 and 20 for 1260 seconds and 300 seconds, respectively, on DOY 334. Upon carrousel removal from the spectrograph a piece of glass plate floated out. It was later identified as an SC-5 film plate fragment, from crew descriptions. The SC-5 plates had been loaded in positions 29 through 34 in the carrousel. The crew reported that the carrousel was misaligned 45 degrees from the 00 position, indicating that plate 33 or 34 was aligned with the film gate, rather than plate 19 or 20, as had been planned to be exposed. A plate was protruding and the crew pushed it into the carrousel and stowed the carrousel. On DOY 335 at 1515, the crew reported the SA stowage was completed and no glass was observed in the unit. Apparently the broken glass had impeded the carrousel movement to the proper position.

On DOY 339, a procedure was sent to the crew for carrousel 2-2 realignment to correct for the reported 45-degree misalignment. The procedure called for manually rotating the carrousel so that the 00 plate was positioned to the film gate for normal operation. The procedure was performed without any problems.

S183 was operated a third time on DOY 340. The first eight plates of carrousel 2-2 were exposed, per PAD, and upon carrousel removal the crew reported that the carrousel's hub was offset 90 degrees from the 00 position. This meant that the SA Plate indicator had not been reset to the 01 position before carrousel removal (see note below). This was confirmed during the next operation. Such a failure to reset to

zero before removal should have caused plate 08 to be pulled from the carrousel and left in the SA. The crew was instructed to search for a plate in the SA but none was found. It was learned after the carrousel was returned to earth that plate 08 was still in the carrousel.

> NOTE: The checklist was vague in this area; i.e., the step in the S183 operation section which requires the advance of the film carrousel to the 01 display position was only applicable if the carrousel was to be removed at the next operation; and, in addition, this step had not been cross-referenced or repeated in the S183 stow section of the checklist. Stowage usually took place at a different time than operation.

An alignment procedure was sent to the crew on DOY 345 to assure that the carrousel was in the 00 position for the next operation. This procedure was accomplished. However, pliers had to be used to rotate the carrousel hub about 45 degrees to the 00 position (outside the SA). No loose glass fragments were reported (see Anomaly No. 3). The 45-degree offset roughly corresponds to plate 32 on the carrousel. The broken glass left within the carrousel in position 33 or 34 could have been the cause of the 45-degree offset as the carrousel drive mechanism would continue to advance without driving the carrousel if friction was high enough. The unit was designed in this manner to protect the drive mechanism.

On DOY 347 the fourth SA operation was performed, the second operation for carrousel 1-1. The PAD scheduled frames 21 and 22, and the crew stepped the carrousel to 21 and made an exposure. They reported getting a late start on the planned 1260-second exposure, then reported exposing plate 22 and terminating it early due to sunrise, thereby obtaining a 240-second exposure instead of the scheduled 300 seconds. It was discovered at this time that the SA had not been reset to 01 but to 09 initially, and they had actually exposed carrousel plates 13 and 14. Per ground instructions, the crew then advanced the SA indicator to 09 to reset the carrousel to plate 00 for removal. Upon removal it was reported that a slide was sticking out. The slide was intact and the crew pushed it back in the carrousel without identifying its number. At this time, another piece of the SC-5 plate glass (believed to be a corner) was found (SC-5 type plates were identifiable by the emulsion-free border on the glass and the yellowish emulsion). It was concluded that the broken glass was jamming the carrousel.

The crew was requested to ascertain the carrousel alignment. The ATM pointing overlay was used to estimate the alignment mark, a drill hole placed on the center hub face of carrousel 1-1, offset

angle from the film gate. The crew reported that the drill hole was located at approximately 1150; i.e., clocked about 5 to 10 degrees CCW from the film gate position (1200 o'clock position).

The crew reported difficulty inserting carrousel 1-1 into the SA on DOY 003. Upon carrousel removal to investigate the interference, the crew reported that a "part of the plate" floated out of the SA and that the carrousel index marks were not at 1200, but 1100 (i.e., plate 35). He reinstalled the carrousel and exposed plate 15 per PAD. He then exposed plates 21, 22, and 23 and performed the malfunction procedure. This procedure was supposed to remove plate 29 from the carrousel by interrupting an exposure and removing the carrousel while plate 29 was still in the SA film plane. This blank slot (which would result from the removal of plate 29) was planned to be used for future carrousel 1-1 removals and prevent the broken plates in the higher number positions from rotating past the film gate and possibly jamming the carrousel rotation. The malfunction procedure did not remove plate 29 as expected. The crewman reported that no plate was pulled from the carrousel when it was removed, nor was it ejected from the SA when he reapplied power. In addition, when he put his finger into the carrousel to depress the plunger to realign it, he reported that the "E" clip that retained the spring was broken and the spring came out. This spring was used to force the carrousel into the indexing detents. Since there were no spare "E" clips onboard Skylab, the spring was not replaced. This did not eliminate the carrousel use. However, it did require that the crew check the orientation marks prior to each usage and use extreme care when inserting the carrousel into the SA. Any sudden torquing around the cylindrical axis would have misaligned the unit and caused a difficult, if not an impossible, installation.

On DOY 021 the crew reported that the film had jammed in the DAC at about the 79 percent remaining position. The crew checked it because they remembered that it had read this value earlier and were curious as to why it had not changed. An electrical malfunction had just occurred and no power was being supplied to the DAC by the SA power cable. This was verified by attaching another DAC to the cable and attempting to operate it without success. It was determined, through an SA malfunction procedure operation by the crew, that a DAC camera circuit fuse within the SA was blown. The fuse apparently had blown as a result of the film jam and caused the entire SA to be inoperable. This malfunction was duplicated on the qualification unit in Marseilles, France, by the developers and a fix was suggested to return SA operation to normal without the DAC. The fix bypassed the internal fuse providing 28 VDC power to the camera circuit via a jumper wire which connected pin 1 of the SA DAC connector to pin 7 of the adjacent test connector. The jumper wire was made by splicing two multimeter adapter leads together and plugging them directly to the SA male connector pins. The fix was accomplished on DOY 027 and SA operations continued.

After SL-4, post mission development of SA photographic plates revealed that most of the plates contained no data, in fact, only plate 19 in carrousel 1-1 had been exposed and no plates in carrousel 2-2 were exposed. It was speculated that the spectrograph had been desynchronized.

The carrousel was rotated by a grooved axis that had as many grooves as there are plates (36 plates). The axis was controlled by a motor. The motor was geared so that two pulses were required to provide one turn of the motor. One pulse corresponded to 1/2 a groove, (i.e., half the distance between two plates) consequently, there was a desynchronization risk when an uneven number of pulses were produced by an electrical mishap, or if the carrousel was mechanically prevented from rotating. Broken glass was believed to have interferred with rotation which led to desynchronization or mechanical failure of the SA.

During the mission, it was not evident that the unit was desynchronized. It was thought that, when desynchronized, the carrousel could not be remounted once it had been withdrawn. This had been verified on the ground with the qualification and training carrousels. However, post mission investigation revealed that the flight carrousels had been modified so that there were no sharp ridges in the grooves. This allowed the flight magazines to be mounted very easily even though the camera was desynchronized.

In addition, no indication of a desynchronization problem was evident on the ground via the telemetry. The discrete signals telemetered to the ground by the SA were named: 1. plate return to carrousel, 2. plate in focal plane, and 3. shutter open. This data, if received as named, was sufficient to obtain an exposure history or SA status. However, these signals were not of the direct indication type. Rather, the plate status (position) was inferred by the SA film transport mechanism operations which actuated the telemetry signals without requiring a plate to be actually present. Therefore, telemetry signals were received without a plate actually being transferred to the focal plane and the ground was unaware of a problem.

D. Experiment S228 - Trans-Uranic Cosmic Rays

The Principal Investigator for Experiment S228 is Dr. P. Buford Price, Physics Department, University of California, Berkeley, California. The experiment hardware was developed by the Space Sciences Laboratory, University of California, Berkeley, California.

1. Experiment Description

a. Objectives. The objective was to provide a detailed knowledge of the relative abundances of nuclei with atomic number (Z) greater than 26 in the cosmic radiation, and specifically to observe and identify as many trans-uranic nuclei as possible. The data obtained will help determine upper limits on the super-heavy cosmic ray flux with Z greater than 110, and the cosmic ray energy spectrum (from about 150 to 1500 MeV/nucleon) with Z = 26, Z greater than 60, and Z greater than 83.

b. Concept. This experiment was to utilize multi-sheet plastic detectors mounted in the OWS for exposure to cosmic radiation. The cosmic rays would penetrate the detector packages, thereby streaking the plastic sheets. Upon return to earth, these plastic sheets would be chemically etched and the cosmic ray tracks analyzed by measurement of the etched track lengths at the top and bottom of each sheet where the cosmic ray has penetrated. This track length is proportional to the square of the ionization rate of the particle; measurements of track size in many successive sheets provide accurate values for atomic number and energy of that particle.

c. Hardware Description. The experiment consisted of two harness assemblies, each containing eighteen detector modules. Each detector module contained thirty-two sheets of Lexan polycarbonate, each 7" x 8" x 0.010" thick, wrapped in aluminum foil tape. These two harness assemblies were located near the OWS outer wall and suspended between floors near the wardroom compartment (see figure III-15). The detector modules (see figure III-16) were exposed to cosmic rays that penetrated the walls of the OWS. Some rays stopped within the detectors; others passed through them.

One additional detector was launched on SL-4 and deployed on an external clipboard during the first EVA. An aluminum angle was added to one end of the detector to facilitate clamping to the clipboard.

2. Experiment Operation. This experiment was completely passive, requiring only detector module deployment retrieval. A basic requirement was to expose the detector modules to cosmic rays for a minimum of 100 square-foot-days. After this exposure, the modules were returned to earth for analysis.

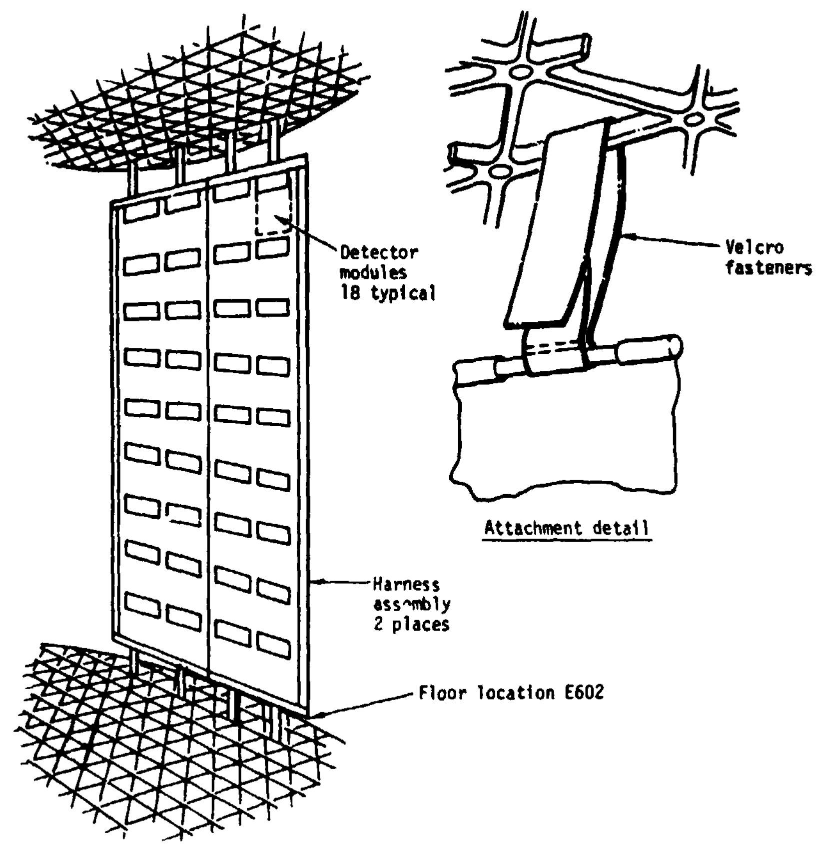

FIGURE III- 15 S228 DEPLOYED CONFIGURATION

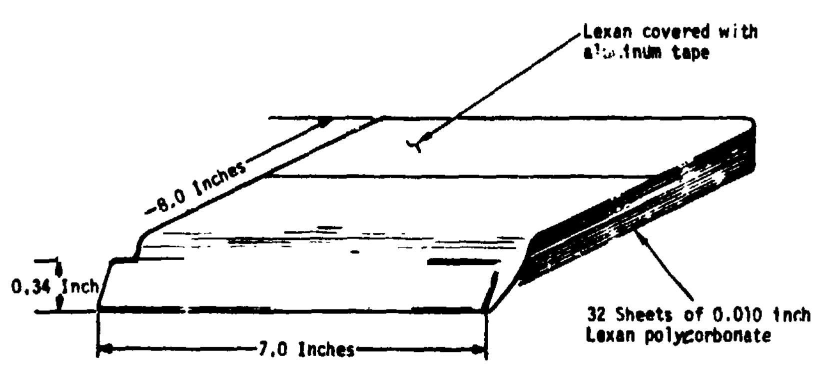

FIGURE III-16 S228 DETECTOR MODULE

The two experiment harness assemblies were deployed on DOY 149 during SL-2 and remained passive, with no further crew involvement, until the end of SL-3, when one detector module was removed and returned to earth. The remaining 35 modules were retrieved on DOY 35 during SL-4. During this mission, a decision was made to leave one module aboard for retrieval on any future visit to Skylab. This module was deployed in the MDA on the Experiment S009 carrier frame, using tape pull tabs. This location was chosen for convenient access by a suited astronaut.

During the first SL-4 EVA on DOY 326, one modified detector module (resupplied on SL-4 launch) was deployed on an external clipboard attached to a universal mount located on the S10 handrail. This module was exposed to cosmic radiation until retrieval during the last EVA, on DOY 34.

3. Experiment Constraints. The experiment constraints were successfully met during the mission.

4. Hardware Performance. The S228 experiment hardware was extremely simple and performed as designed, i.e., contained and exposed thirty-seven detector modules to cosmic radiation.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

Three operational changes were made during the mission which required additional mechanical interfacing. These were: the early return of one detector module in the SL-3 Command Module, deployment of one external module, and deployment of one detector module on the Experiment S009 carrier frame assembly. No problems were encountered as a result of these changes.

6. Return Data. One detector module was returned at the end of SL-3 and thirty-five at the end of SL-4. These modules were released to the PI at the University of California, Berkeley, California.

7. Anomalies. There were no reported S228 anomalies during the mission.

E. Experiment S230 - Magnetospheric Particle Composition

The Principal Investigators for Experiment S230 are Dr. Don L. Lind, Lyndon B. Johnson Space Center, Houston, Texas, and Dr. Johannes Geiss, University of Bern, Bern, Switzerland. The experiment was fabricated by the Johnson Space Center, Houston, Texas, and the University of Bern, Bern, Switzerland.

1. Experiment Description. The magnetospheric particle composition experiment employs the technique of capturing particles in layers of foil. The foils are then returned for analysis. This was the technique applied to solar wind composition measurements (SWC) in the Apollo SWC experiments.

a. Objectives. The objectives were: to measure the fluxes and isotopic composition of the noble gas components of precipitating magnetospheric ions; to obtain an indication of their relative energies; and to determine the particle source. The experiment was to obtain overall information on the fluxes of particle precipitation and to obtain long-term averages for the fluxes of particles precipitating into the atmosphere. Such averages have not previously been determined and it is not known whether the bulk of global precipitation takes place in the aurorae region, or whether quiet precipitation covering a larger fraction of the globe is dominant.

b. Concept. An energy absorption technique is used to collect magnetospheric ions and particles. Multilayered aluminum, aluminum oxide, and platinum foils are to be exposed to the radiation environment whereby the particles will implant themselves within the foils. The foils are then returned to earth for laboratory analysis. The analysis, employing an ultra-high vacuum mass spectrometer will determine the isotopic abundances. By using multilayered foils and stepwise heating, estimates can be made of the original energy of the entrapped particles. The source of the particles is determined from both the abundance data and the energy. The isotopic abundances of the noble gases (He^3, He^4, Ne^{20}, Ne^{21}, Ne^{22}, Ar^{36}, Ar^{38}, and Ar^{40}) in the solar wind and the terrestrial atmosphere differ by such a large factor that they can serve to identify the source of the particles entrapped in the foil collectors or to establish the relative source strengths in an admixture of particles. The energy resolution will allow a distinction between ions stemming from the hot plasmas ($\sim 10^4$ eV) in the magnetosphere and particles precipitating from the inner parts of the Van Allen belts ($\sim 10^6$ eV), if the fluxes of the latter are high enough to be detectable.

The foil method of capturing ions in the kilo electron volt (KeV) range has been successfully applied to solar wind composition measurements in the Apollo program, and in sounding rocket experiments to study the composition and nature of primary auroral particles. The capture probabilities of aluminum, aluminum oxide, and platinum surfaces have previously been determined. Above one KeV the capture probability

is high and very nearly constant over a wide energy range. Below one KeV the trapping efficiency decreases but the particles are still detectable above the experiments threshold of a few hundred eV.

c. Hardware Description. The equipment consisted of sheets of aluminum and platinum collecting foils mounted on a flexible backing material. These collectors were mounted in cuff form on the AM deployment assembly before SL-1 launch as shown in figures III-17 and III-18. Originally there were four cuffs mounted on two spool assemblies clamped around the truss tube assembly which ran from the Fixed Airlock Shroud EVA work station to the ATM support structure point. The two mounting spools are shown installed before SL-1 launch in figure III-19. The spools were mounted adjacent beneath the D2 EVA handrail in the second and third openings in the handrail supports from the truss FAS end as depicted in figure III-20. This location was chosen because: handrails already existed in this area which simplified EVA operations; the area had a reasonably unobstructed view in the anti-solar direction; and the shading from the ATM panel located below the truss would reduce the foil temperature.

The types of collectors used included two outer collectors, two inner collectors, and one modified collector for deployment during EVA. The two outer collectors were 16½ x 21 inches, the two inner collectors were 15¼ x 21¼ inches and the modified collector was 16½ x 22 inches. All collectors consisted of a backing layer of Armalon supporting the foils which served as the collecting surface. The foils were attached to the Armalon by an adhesive tape. Each collector had a fabric handle suitable for the EVA operations.

2. Experiment Operation. The experiment was launched on SL-1 with two collector cuffs to be retrieved both on SL-3 and SL-4. Three collectors were returned on SL-3 because of surface contamination deposited on the two outer collectors during SL-2 fly-arounds. One new collector was launched on SL-4 and deployed during the first SL-4 EVA with two collectors retrieved during the last EVA and returned. Table III-7 summarizes these collector events. Table III-8 summarizes the exposures of the collectors.

TABLE III-7. COLLECTOR SEQUENCE OF EVENTS

Collector	Deployed	Retrieved
Inner, Aft Spool	Mounted Before SL-1 Launch	SL-3, DOY 265
Inner, Forward Spool		SL-4, DOY 34
Outer, Aft Spool		SL-3, DOY 213
Outer, Forward Spool		SL-3, DOY 213
Modified, Aft Spool	SL-4, DOY 326	SL-4, DOY 34

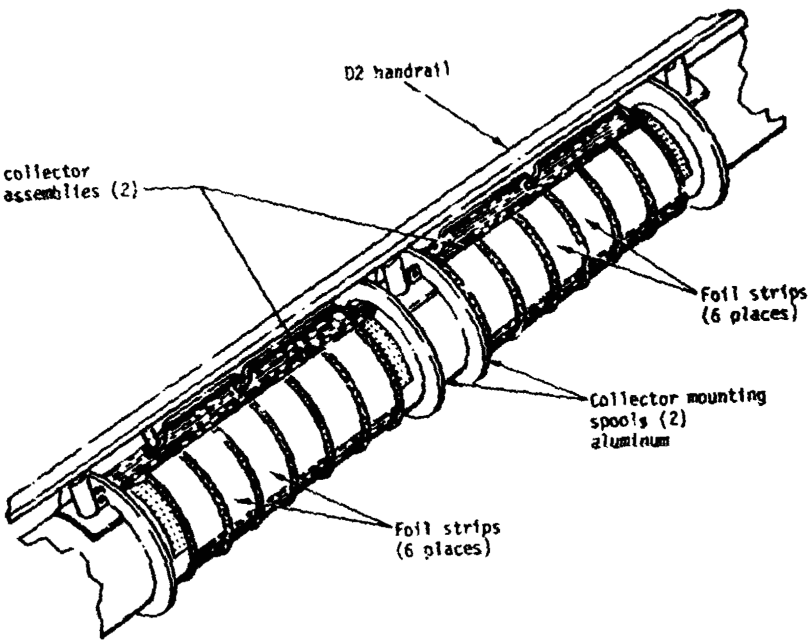

FIGURE III-17. S230 COLLECTOR CUFFS DEPLOYED

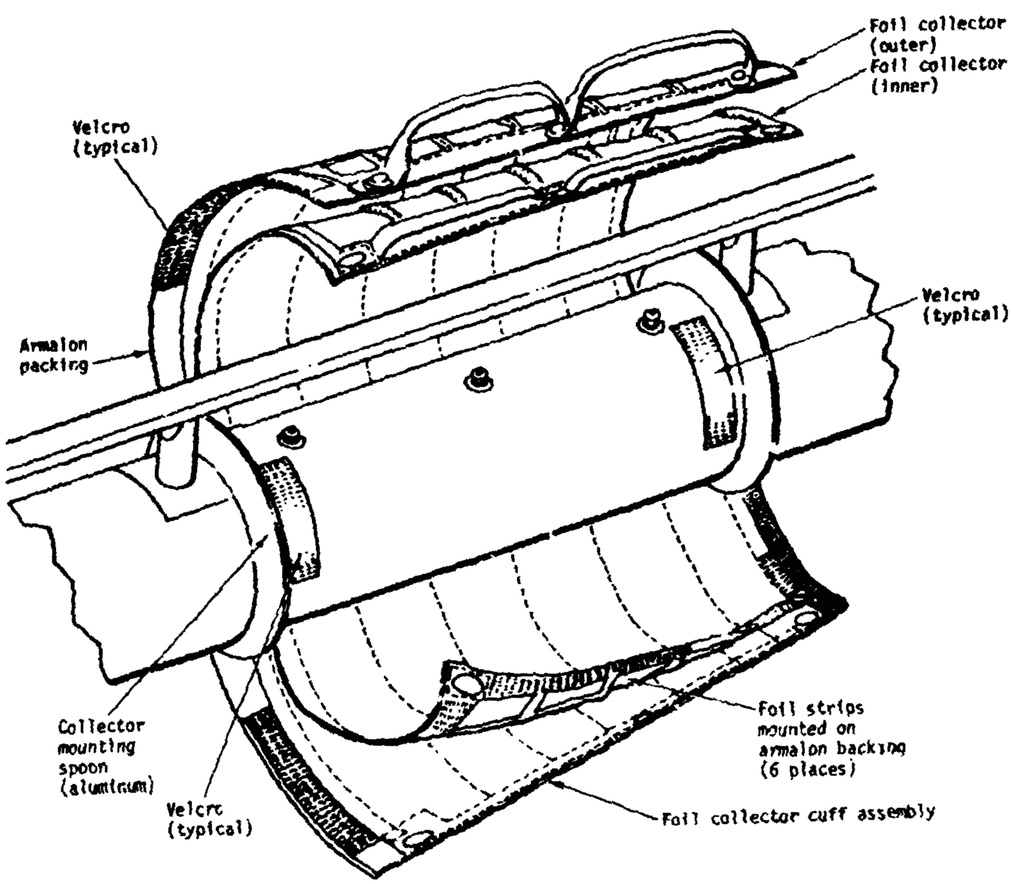

FIGURE III-18. COLLECTOR CUFF

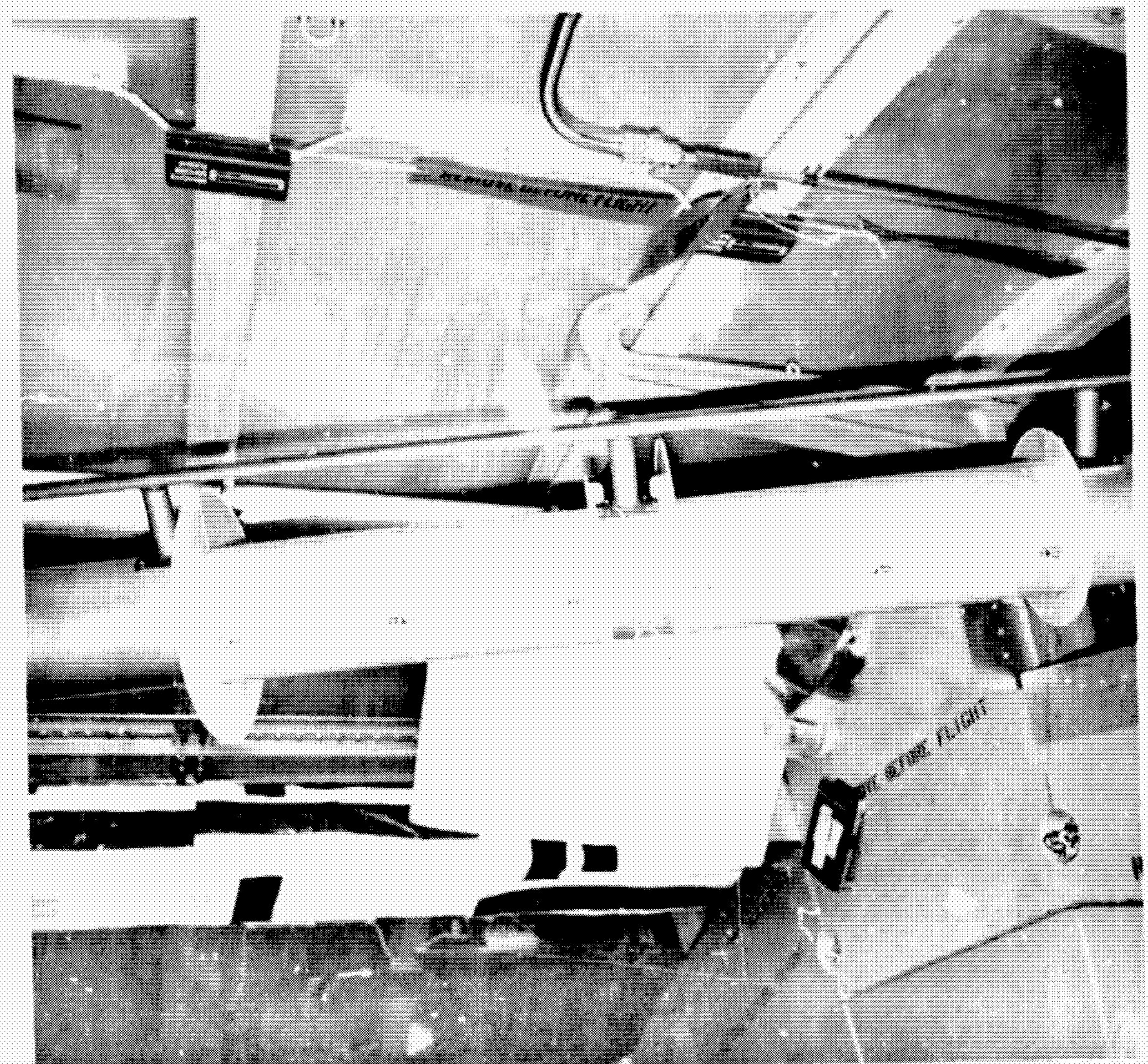

FIGURE III-19. SPOOLS MOUNTED PRIOR TO SL-1 LAUNCH

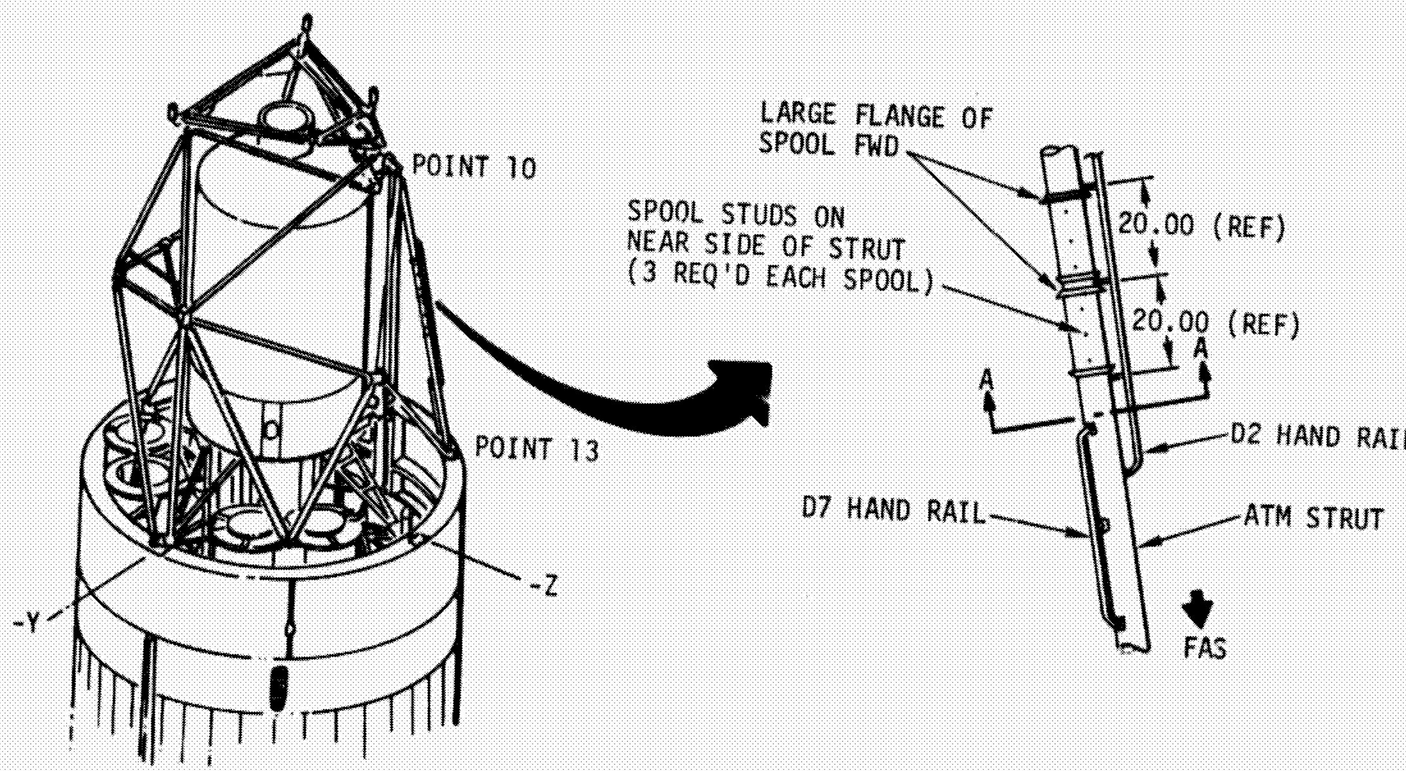

FIGURE III-20. EXPERIMENT S230 - VEHICLE LOCATION

TABLE III-8. COLLECTOR EXPOSURE TIME

Collector	Begin Exposure	End Exposure	Total Time
Inner, Aft Spool	DOY 218, 2341	DOY 265, 1335	47
Inner, Forward Spool	DOY 218, 2344	DOY 034, 1943	181
Outer, Aft Spool	DOY 134, 1745	DOY 218, 2341	84
Outer, Forward Spool	DOY 134, 1745	DOY 218, 2344	84
Modified Aft Spool	DOY 326, 2023	DOY 034, 1951	73

3. Experiment Constraints. The experiment constraints were successfully met during the mission.

4. Hardware Performance. The experiment hardware was successfully launched and deployed on SL-1. The outer collector cuffs on both spools were exposed to the desired environment. There were no significant hardware problems from installation through launch and deployment.

The experiment operated in a passive configuration during SL-1/2 with no crew involvement.

The two outer collectors were retrieved during the first SL-3 EVA. These collectors will contain useful data but also have surface contaminants deposited on the foils from the SL-2 and SL-3 docking and fly-around maneuvers. Such deposits may complicate data analysis. The inner collectors were protected up to this time and started collecting particles upon removal of the outer collectors. During the last EVA of SL-3, the inner collector of the aft spool was retrieved. All three collectors were returned in the SL-3 CM.

Temporary stowage of the three collectors was required from retrieval until the end of the mission. These collectors were stowed in one of the Skylab food freezers, thus reducing the chance for loss of captured particles from the foil by diffusion, particularly on the outer collectors which were in temporary stowage approximately 50 days. The cuffs retrieved during the last EVA were stowed approximately 4 days.

A new collector assembly was deployed on the aft spool during the first SL-4 EVA on DOY 326. During the last EVA, on DOY 34, collector assemblies on both the forward and aft spools were retrieved and returned in the CM on DOY 39.

Subsequent to retrieval both collector cuffs were tethered in the AM. During repressurization the rush of air from equalization valve 311 tore two foil strips of the collectors deployed during the first EVA on the aft spool.

On one strip there were no pieces of foil completely torn loose and the geometry of the panel was completely reconstructed. On the second strip some foil was completely detached. Although the greatest portion of this foil was recovered, some orientation information was lost. This is expected to have only a minor effect on data analysis.

The damage to the aft collector cuff is shown in figure III-21.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. Three collector cuffs were returned on SL-3 and two collector cuffs were returned on SL-4. These consisted of two outer cuffs, two inner cuffs and one modified cuff. These cuffs were returned to Dr. Johannes Geiss, University of Bern, Switzerland.

7. Anomalies. No anomalies were reported during the mission.

FIGURE III-21. S230 AFT COLLECTOR RETURNED FOLLOWING SL-4

SECTION IV. ENGINEERING AND TECHNOLOGY EXPERIMENTS

A. Experiment D024 - Thermal Control Coatings

The Principal Investigator for Experiment D024 is Dr. William Lehn, the Air Force Materials Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base (W-PAFB). The thermal control coatings trays and material return container were developed by Goodyear Aerospace Corporation, Akron, Ohio, under contract to W-PAFB. The polymeric film strip trays were developed at W-PAFB.

1. Experiment Description. It is noteworthy that experiments D024 and M415, both entitled "Thermal Control Coatings," complemented each other. M415 investigated degradation effects during the launch phase (using telemetry) and D024 investigated effects of the orbital phases. Experiment D024 was the first U.S. opportunity to perform detailed examination of exposed coating samples that were chemically and physically unaltered following retrieval from the vacuum of space.

a. Objectives. The objectives were to: evaluate near-earth space environment exposure effects on selected thermal control coatings and polymeric film strips; and establish calibration values for further ground simulations. The returned specimen analysis would enable more accurate insights into the mechanism of long-duration degradation, and would provide improved damage theories.

b. Concept. The environmental effects are to be measured by taking spectral reflectance data on a control group of thermal control coating specimens before and after exposure to controlled environments in ground laboratories. These data are to be used for comparison with similar data obtained from identical samples exposed to the Skylab space environments. Since recombination with normal atmosphere would occur for certain of the flight specimens, it would be necessary that retrieval and return to earth be in an evacuated, sealed container and placed in a specially prepared vacuum chamber. The container is to be remotely opened after the chamber is evacuated and then the sample tray removed. Each specimen is to be removed from the tray and subjected to spectral reflectance measurements. The spectrum of interest covers the visible and extends into the near IR and UV ranges. Upon test completion, the chamber is to be repressurized with clean, dry gas, and the container removed for polymeric film strip analysis.

Mechanical, electrical and optical properties of the polymeric film strips are to be measured on both the control samples and the flight samples. Control strips are to be subjected to measured, simulated radiation to provide calibration and comparison data. Long-term ultraviolet exposure is of primary interest, since it is the main factor in polymeric film degradation. Mechanical characteristic evaluation will be through measurement of tensile strength, modulus of elasticity, and percent elongation. Dielectric strength, dielectric constant, resistivity and dissipation factor will comprise the electrical measurements. Both percent transmission and frustrated multiple internal reflection spectra will be recorded to obtain optical data.

c. Hardware Description. The experiment hardware is shown in figure IV-1. The experiment flight package (figure IV-2) consisted of four panels and two return containers. Two panels held 36 thermal control coating samples each. The samples were 2.54 cm diameter discs coated with various selected thermal control coatings. The other two panels contained 32 strip samples each of eight different types of polymeric film. The polymeric strips were 7.62 cm long by 0.635 cm wide and 1.27 cm wide. All panels were square plates, about 17 cm on a side and 0.6 cm thick. Each had a flexible handle to assist in handling. The panels were attached to the airlock truss assembly prior to launch, using snap fasteners and pip pins (figure IV-3). The samples were protected from the launch environment by the payload shroud.

2. Experiment Operation

a. Summary. Material sample exposure was accomplished as planned on SL-1/SL-2 and SL-3. However, calibration values for ground simulation of space environment could not be obtained due to an unexpected layer of contamination covering all exposed hardware. Efforts were redirected from analysis of radiation effects to analysis of contamination effects and additional samples were resupplied for test on SL-4.

b. Experiment Operation SL-1/SL-2 and SL-3. The first two sets of D024 thermal control coatings and polymeric film strips were exposed to the outer space environment commencing DOY 134 at 1845 GMT. Exposure was initiated when the payload shroud was jettisoned from the Saturn Workshop. The samples were subsequently retrieved by the crewmen during space walks on DOY 170 (during the first manned phase) and DOY 265 (during the second manned phase). The first set of samples was therefore exposed for 36 days and the second set for 131 days. Each set consisted of two panels, one each of thermal control coatings and polymeric film strips.

Sample retrieval was accomplished as planned and no problems were encountered with the hardware or procedures. The crewman removed

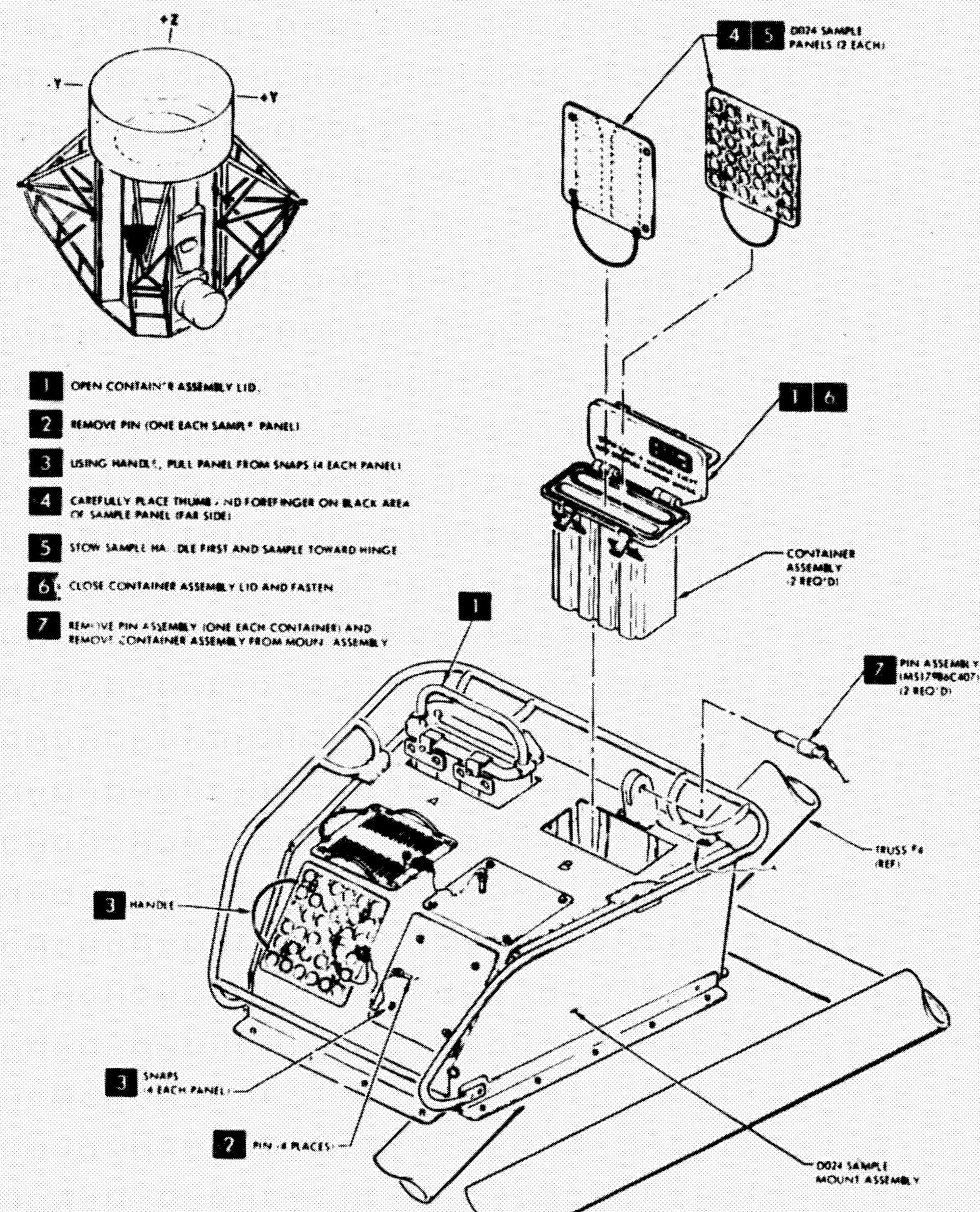

FIGURE IV-1 TRUSS 4 - D024 STOWAGE

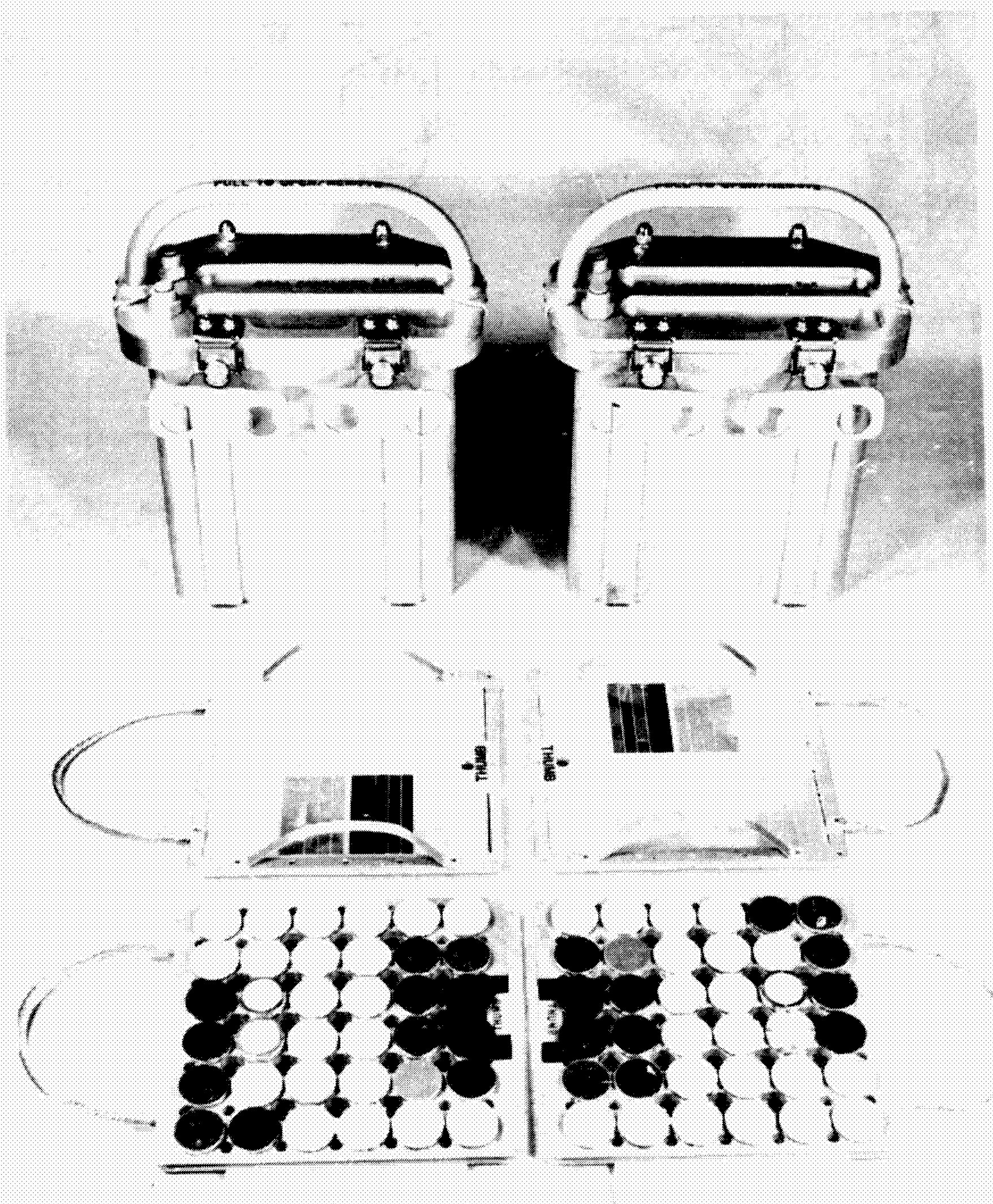

FIGURE IV-2 DO24 EXPERIMENT HARDWARE

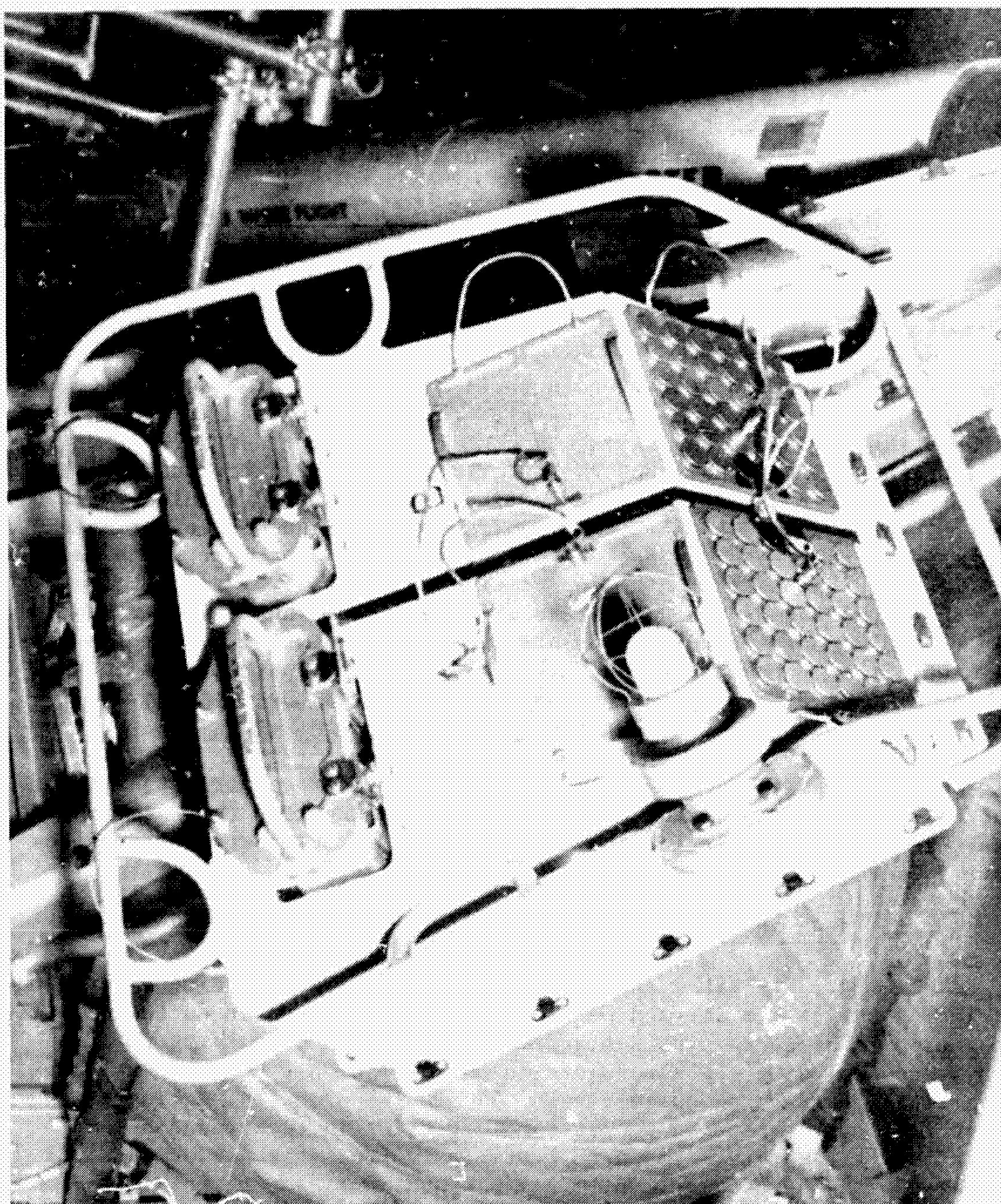

FIGURE IV-3 DO24 FLIGHT HARDWARE

the panels and inserted them in the return containers, which were stowed adjacent to the experiment, and sealed them while in the space vacuum. The return containers were then stowed for return to earth and subsequent delivery to the PI within four days of Command Module recovery. The sample panels were not exposed to the atmosphere during delivery.

c. Additional Operations on SL-4. As a result of contamination data obtained on SL-1/SL-2 and SL-3, approval was obtained to launch one back-up thermal control sample panel, one back-up polymeric film strip panel and one back-up material return container on SL-4. Hardware deployment was accomplished during EVA on DOY 326. Difficulty was experienced installing the sample trays because the hardware design had not considered installation in orbit by a suited crewman. Nevertheless, the installation was successful. The return container lid was not closed, thus allowing the Skylab external environment and solar radiation to impinge upon the seals and the interior. Retrieval was accomplished on DOY 034 after a total of 73 days exposure. The SL-4 samples avoided control rocket exhaust contamination from the Command Module during the fly-around, docking and undocking maneuvers. The container, with samples, was returned and delivered to the PI within four days. At that time, it was found that atmospheric pressure existed inside the container, and the thermal control coating tray had been inserted with the samples facing away from, rather than toward, the hinge. The instructions on the inside of the material return container lid stated that the tray be inserted with the samples facing the hinge.

3. Experiment Constraints. The experiment constraints were successfully met during the mission, with the exception that atmospheric pressure was present inside the SL-4 material return container upon delivery to the PI.

4. Hardware Performance

a. SL-1/SL-2 and SL-3 Performance. The experiment hardware performed satisfactorily and no problems were encountered during normal operation. The containers performed the functions of holding sample trays and excluding the atmosphere on these missions. The thermal control coatings trays adequately held the samples prior to, during, and after flight, and enabled proper sample testing in the ground-based laboratory after return to earth. Similarly, suitable performance was achieved with the polymeric film strip trays.

The crew did report that some samples appeared to be coming debonded. This was not observed in the ground-based laboratory. The crew further stated that the material return containers worked well and that the experiment stowage for return was simple.

b. SL-4 Performance. Some difficulty was experienced installing the disc tray during EVA on SL-4, but since that was not originally planned it was not considered as a serious problem or a hardware malfunction. Atmospheric pressure was noted inside the container returned from this mission. The presence of this pressure is currently unexplained.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission except some difficulty was experienced during the SL-4 EVA installation.

6. Return Data. Data returned to the PI consisted of one thermal control coating tray and one polymeric film strip tray in a material return container after each mission. All returned hardware showed evidence of a yellowish-brown contamination that was apparently a function of exposure time and sunlight. This contamination effect obscured the expected sample degradation due to solar radiation. It also obscured any atmospheric recombination which could have affected the SL-4 samples due to loss of vacuum on return. This contamination source is now under investigation.

7. Anomalies

a. SL-1/SL-2. None.

b. SL-3. Some sample debonding was noted by the crew. However, this condition was not evident upon examination of the returned samples.

c. SL-4. The return container did not maintain the samples in a vacuum-tight environment for reasons which have not been determined. The thermal control coating tray had been inserted with the samples facing away from, rather than toward, the hinge. The desired orientation was described by a decal located inside of the material return container lid. These instructions were required to enable sample handling and testing inside the vacuum chamber at the PI's laboratory. Even though the samples were not maintained in a vacuum-tight environment, they are considered usable for contamination analysis.

B. Experiment M415 - Thermal Control Coatings

The Principal Investigator for Experiment M415 is Mr. Eugene C. McKannan, Materials Division, Astronautics Laboratory, Marshall Space Flight Center (MSFC/S&E-ASTN-MM). The experiment equipment was developed and built by MSFC.

1. Experiment Description

a. Objectives. The objective was to determine the degradation brought about by prelaunch, launch, and space environments on the thermal absorption and emission characteristics of various coatings commonly used for passive thermal control.

Data analysis was to provide general information for thermal design of future spacecraft and specifically in the selection and development of thermal coatings which will better maintain their "whiteness" (high reflectivity) through the launch environment.

b. Concept. The experiment objective was satisfied by subjecting three different types of thermal control coating materials (and a black control specimen) sequentially to four exposure conditions on the SL-2 Instrument Unit (IU) exterior during prelaunch, launch, and orbital operation.

The coatings' degradations were determined by the change in thermal properties. The specimen samples were mounted on temperature sensors which were thermally isolated from the surrounding structure. The specimens' temperatures were monitored and telemetered when in contact with selected ground stations.

c. Hardware Description. The specimens were arranged on panels in four rows of three each, as sketched in figure IV-4. Two panels were placed on the IU in different orientations relative to the launch vehicle retrorocket firings. (One in line, one not in line - see figure IV-5.)

The thermal control coatings were:

S-13g zinc-oxide pigment in methyl silicone binder, rough surface.
Z-93, zinc-oxide pigment in sodium silicate binder, medium rough surface.
HWX, MSFC composite of synthetic mica, potassium silicate and zinc-oxide.

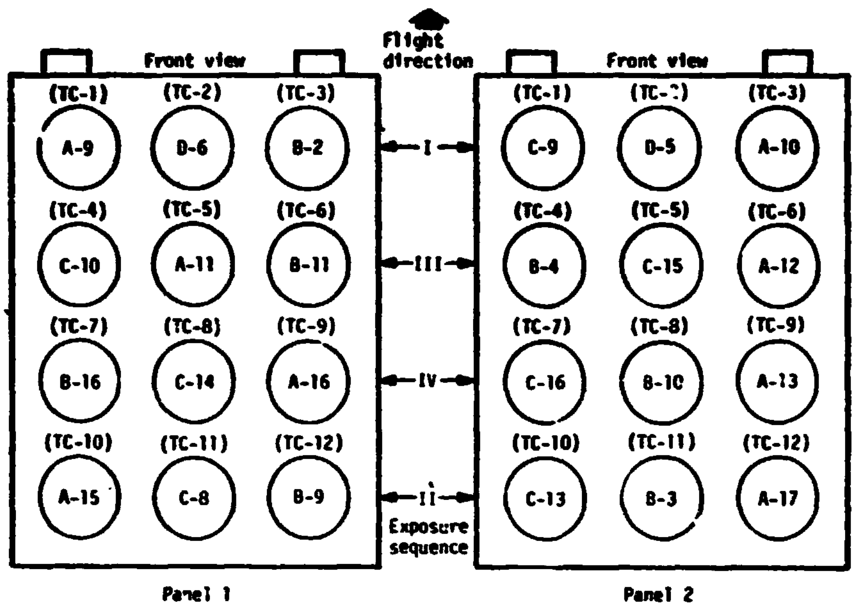

FIGURE IV-4 M415 THERMAL CONTROL COATINGS FOR PANELS 1 AND 2

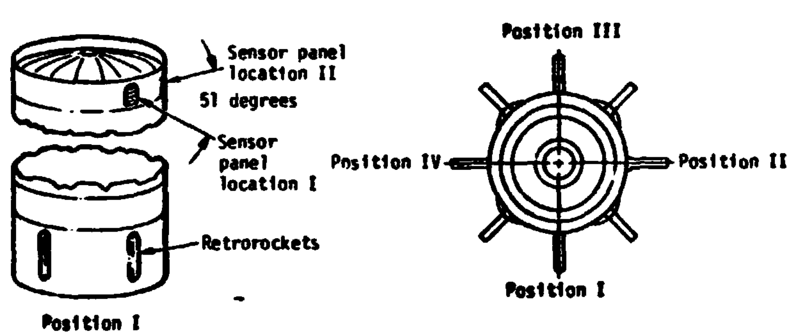

FIGURE IV-5 M415 SENSOR PANEL LOCATIONS

BC, black control, CAT-ALAC black, medium rough surface.

2. Experiment Operation. The experiment was launched and operated attached to the IU exterior of the SL-2 launch vehicle which carried the first Skylab crew into earth orbit on May 25, 1973. There was no crew participation required in the experiment deployment, operation, or data collection; in-flight performance was accomplished automatically by the launch vehicle computer and data systems.

The covers were removed, two at a time, (one from each panel) exposing the samples in the sequence shown in the following table:

TABLE IV-1 SAMPLE EXPOSURE SEQUENCE

Exposure Sequence	Cover No. Opening Sequence	Sequence Event	Event Time (GMT)	
			Scheduled	Actual
I	1	Just prior to launch	-24 hrs GET	-36 hrs GET (approx.)
II	4	Just prior to retro firing	13:02:22.2	13:02:23
III	2	Just prior to LES tower jettison	13:02:39.6	13:02:40
IV	3	After spacecraft separation	13:55:42.1	13:55:41

All openings were acceptably close to the scheduled times.

The protective covers were removed by sealed pyrotechnic actuators. Removal of each cover exposed three new samples. By exposing the samples at different intervals, it was possible to correlate the effects of the individual environments experienced. Data were collected from launch through three orbits and part of a fourth, a duration of 20,760 seconds.

3. Experiment Constraints. The experiment constraints, all operational, were successfully met during the mission.

4. Hardware Performance. The experiment hardware performed satisfactorily. The six remaining protective covers were deployed after launch at the scheduled times in accordance with the flight plan. This

was confirmed by telemetry records of the cover release event signals and the corresponding step changes in the relevant specimen temperatures as shown in table IV-1. All 26 temperature sensors (24 specimen and two panel sensors) worked properly within the calibrated ranges, and usable data was obtained from each of them.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. Return data consisted entirely of telemetry. In summary, the experiment data was comprised of the following:

a. Event signals verified the deployment of the covers. These properly coincided with the programmed event sequence.

b. Temperatures of the 12 specimens in each panel (and the panels themselves) were monitored at the rate of 12 samples per second over selected ground stations. These were Hawaii, Honeysuckle, Madrid, Texas and Goldstone. Equilibrium temperatures were reached on the daylight portion of two orbits. This condition provided all the necessary information for calculating the absorptivity/emissivity ratios for all specimens, from which their surface conditions could then be determined.

7. Anomalies. None were encountered.

C. Experiment M487 - Habitability/Crew Quarters

The Principal Investigator for Experiment M487 is Mr. Caldwell C. Johnson, Chief of the Spacecraft Design Division at the Lyndon B. Johnson Space Center, Houston, Texas. The M487 Experiment Instrumentation Developer was McDonnell Douglas Astronautics Company - Western Division, Huntington Beach, California. This report is intended to provide a brief overview of the experiment and to document the functional adequacy of the flight hardware associated with the experiment. A comprehensive report of the experiment findings will be published under separate cover by the Principal Investigator.

1. Experiment Description.

a. Objectives. The primary objective was to provide useful habitability evaluation data for future manned spacecraft design. The data was to include astronauts' evaluations of: routine daily activities and self-sustenance chores (i.e., work tasks, sleeping, eating, hygiene tasks, etc.); the ease or difficulty experienced when moving about the Orbital Assembly (OA); and the adequacy of various habitability features and on-board provisions.

b. Concept. Subjective data were periodically obtained from each crewman on OA environment, internal architecture, adequacy of mobility aids and restraints, food and water, garments and personal accouterments, personal hygiene, housekeeping, internal communications, and the adequacy of off-duty activity provisions. Film sequences of selected activities which demonstrated crew adaptability to zero gravity, and measurements of environmental parameters within the OA, were also obtained to supplement the subjective evaluation data.

c. Hardware Description. Portable measuring instruments used by the crew to supplement subjective comments and shown in figure IV-6, are:

Instrument	Application
Velometer (Portable)	For measuring air movement velocity within the OA.
Measuring Tape (Portable)	For measuring distances to evaluate pertinent sizes and locations.
Sound Level Meter (Portable)	For measuring sound pressure levels in the OA.
Frequency Analyzer (Portable)	For analyzing the sound spectrum within the OA

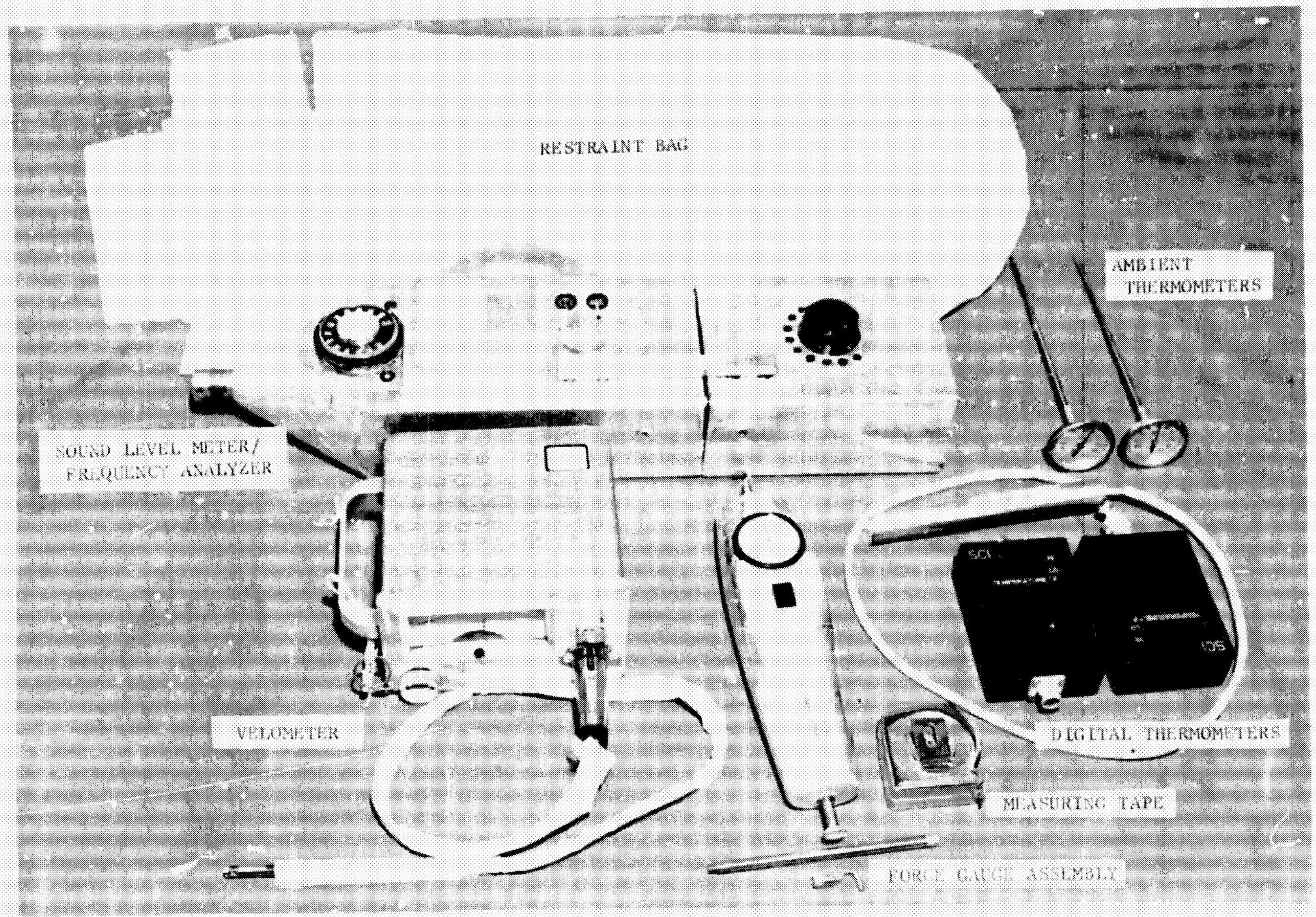

FIGURE IV-6 M487 EXPERIMENT HARDWARE

Instrument	Application
Restraint Bag	For inflight stowage of the assembled sound level meter and frequency analyzer unit, and attached to any location containing snaps.
Ambient Thermometers (Portable)	For measuring ambient OA air and fluid temperatures.
Digital Thermometer (Portable)	For measuring wall temperatures and temperatures of solids and surfaces within the OA.
Force Gauge	For measuring push/pull forces, up to a 50-lb limit, applied by crewmen in flight.

Specific items of hardware were stowed in a three-drawer experiment container, which was stowed in Wardroom Locker W749 (refer to figure IV-7).

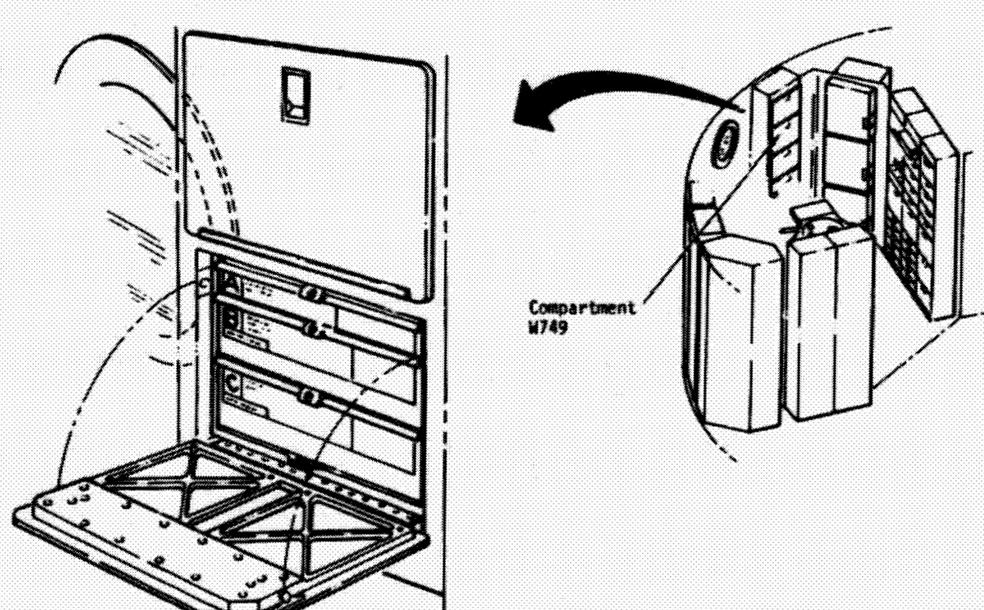

FIGURE IV-7 M487 HARDWARE STOWAGE LOCATION

2. Experiment Operation. Crew tasks and activities associated with the habitability evaluation were arranged and categorized into Functional Objectives (FOs). They were scheduled into the crew daily flight plans at moments of opportunity, and at other times when activities to be photographed were being performed. The functional objectives are summarized in Tables IV-2, IV-3, and IV-4.

Nineteen (19) of twenty (20) baselined functional objectives were performed during the SL-1/2 mission representing 100% of the flight-planned objectives and 97% of the baselined objectives (see table IV-2).

All eighteen (18) baselined functional objectives were performed during the SL-3 mission, representing 100% of both flight-planned and baselined objectives (see table IV-3).

All nineteen (19) baselined functional objectives were performed during the SL-4 mission, representing 100% of both flight-planned and baselined objectives (see table IV-4). Two additional FOs (20 and 21) were approved during the SL-4 mission, and were performed late in the mission. These objectives (special evaluation of "mushroom"-type shoe restraints, and a photographic sequence showing the crew up-dating checklists) were proposed by the PI.

No difficulties were reported by the crew concerning the use of checklists and procedures during the SL-1/2, SL-3, and SL-4 missions, except with the portable sound level meter/frequency analyzer. The reported difficulty during SL-1/2 is discussed in paragraph 4c.

3. Constraints. The experiment constraints were successfully met during the missions.

4. Hardware Performance. Summaries of experiment and other operational usages of the M487 portable measuring instruments throughout the three manned missions are presented in paragraphs 4a through 4e.

a. Digital Thermometer. During activation (DOY 147) on the SL-1/2 mission, the crew used the digital thermometer to obtain random, spot measurements of surface temperatures in the OWS. The following temperature measurements compared closely with the estimated and telemetered values received during the prehabitation period:

Locker W740 (M487 Stowage)	104°F
Locker F555 (IMSS)	106°F
Locker F555 (Food)	110°F
Locker F562 (Food)	116°F
Film Vault	106°F

TABLE IV-2 M487 PERFORMANCE SUMMARY (SL-1/2 MISSION)

FO	ACTIVITY	BASELINE OBJECTIVE	FLIGHT PLANNED OBJECTIVE	PERFORMED
1	Crew Subjective Comments (Early Mission)	X		X
2	Crew Subjective Comments (Mid Mission)	X		X
3	Crew Subjective Comments (Late Mission)	X		X
4	Crew Debriefing (Early Mission)	X	X	X
5	Crew Debriefing (Mid Mission)	X		X
6	Crew Debriefing (Late Mission)	X	X	X
7	Use of Sound Level Meter/Frequency Analyzer	X	X	X
8	Use of Velometer (Moment of Opportunity) Use of Ambient or Digital Thermometers (Opportunity) Use of Force Gauge Assembly (Opportunity) Use of Portable Spot Meter (Opportunity)	X		X
9	Photography, Evening Meal (Early Mission)	X	X	X
10	Photography, Evening Meal (Late Mission)	X		X
11	Photography, Doff Clothing and Ingress Sleep Restraint	X	X	X
12	Photography, Doff Clothing and Ingress Sleep Restraint	X	X	X
13	Photography, Egress Sleep Restraints and Don Clothing	X	X	X
14	Photography, Egress Sleep Restraints and Don Clothing	X	X	X
15	Photography, Clean Mixing Chamber Screen (Early)	X	X	X
16	Photography, Clean Mixing Chamber Screen (Late)	X		X
17	Photography, Trash Airlock Operation (Early)	X	X	X
18	Photography, Trash Airlock Operation (Late)	X		X
19	Photography, Demo. In Waste Management Comp't.	X	X	X
20	Photography, Off-Duty Activities and Personal Hygiene	X		

TABLE IV-3 M487 PERFORMANCE SUMMARY (SL-3 MISSION)

FO	ACTIVITY	BASELINE OBJECTIVE	FLIGHT PLANNED OBJECTIVE	PERFORMED
1	Crew Subjective Comments (Early Mission)	X	X	X
2	Crew Subjective Comments (Mid Mission)	X	X	X
3	Crew Subjective Comments (Late Mission)	X		X
4	Crew Debriefing (First two-week period)	X	X	X
5	Crew Debriefing (Second two-week period)	X	X	X
6	Crew Debriefing (Third two-week period)	X	X	X
7	Crew Debriefing (Fourth two-week period)	X	X	X
8	Use of Sound Level Meter/Frequency Analyzer Use of Velometer (Moment of Opportunity) Use of Ambient or Digital Thermometers (Opportunity) Use of Portable Spot Meter (Opportunity)	X	X	X
9	Photography, Eating Meal (Early Mission)	X	X	X
10	Photography, Eating Meal (Mid Mission)	X		X
11	Photography, Eating Meal (Late Mission)	X		X
12	Photography, Cleaning Mixing Chamber Screen (Early)	X	X	X
13	Photography, Cleaning Mixing Chamber Screen (Mid)	X	X	X
14	Photography, Cleaning Mixing Chamber Screen (Late)	X	X	X
15	Photography, Trash Airlock Operation (Early Mission)	X	X	X
16	Photography, Trash Airlock Operation (Mid Mission)	X	X	X
17	Photography, Trash Airlock Operation (Late Mission)	X	X	X
18	Photography, Restocking Pantry (Mid Mission)	X	X	X

TABLE IV-4 M487 PERFORMANCE SUMMARY (SL-4 MISSION)

FO	ACTIVITY	BASELINE OBJECTIVE	FLIGHT PLANNED OBJECTIVE	PERFORMED
1	Crew Subjective Comments (Early Mission)	X	X	X
2	Crew Subjective Comments (Mid Mission)	X	X	X
3	Crew Subjective Comments (Late Mission)	X	X	X
4	Crew Debriefing (First Two-Week Period)	X	X	X
5	Crew Debriefing (Second Two-Week Period)	X	X	X
6	Crew Debriefing (Third Two-Week Period)	X	X	X
7	Crew Debriefing (Fourth Two-Week Period)	X	X	X
8	Use of Sound Level Meter/Frequency Analyzer (Opportunity) Use of Velometer (Opportunity) Use of Ambient or Digital Thermometers (Opportunity) Use of Force Gauge Assembly (Opportunity) Use of Portable Spot Meter (Opportunity)	X	X	X
9	Individual Crew Height Measurements (Early Mission)	X	X	X
10	Individual Crew Height Measurements (Mid Mission)	X	X	X
11	Individual Crew Height Measurements (Late Mission)	X	X	X
12	Photography, Eating Meal (Early Mission)	X	X	X
13	Photography, Eating Meal (Mid Mission)	X	X	X
14	Photography, Eating Meal (Late Mission)	X	X	X
15	Photography, Cleaning Mixing Chamber Screen (Early)	X	X	X
16	Photography, Cleaning Mixing Chamber Screen (Late)	X	X	X
17	Photography, WMC/Personal Hygiene (Early Mission)	X	X	X
18	Photography, WMC/Personal Hygiene (Late Mission)	X	X	X
19	Photography, Restocking Pantry (Mid Mission)	X	X	X
20	Evaluation of Mushroom Shoes	-	-	X
21	Photogr[illegible] Crew Up-Dating Checklists	-	-	X

No difficulties were reported while using the digital thermometer. However, crew debriefing comments indicated that the thermometer response time was too lengthy. Prior to initial usage, a special investigation was conducted to determine whether estimated temperatures in excess of 125°F would have any effect on the self-contained battery in the unit. Experiment Developer and vendor investigation results indicated that temperatures ranging between the specified limit of 140°F and 160°F could be experienced before battery output and life would be influenced.

Throughout the SL-3 and SL-4 missions, the crew used the digital thermometers to obtain operational measurements of surface temperatures in the OWS. Extensive use was made of the thermometers during the measuring of battery pack and rate gyro surface temperatures to detect any increase in the temperature gradients. The thermometers were used extensively to obtain random, spot measurements of surface temperatures at selected locations throughout the OA. The digital thermometers operated satisfactorily throughout the SL-3 and SL-4 missions.

The digital thermometers were used at the conclusions of the SL-4 EVAs when temperatures of film canisters and other items being brought into the AM were desired. No operational difficulties or problems were reported by the SL-4 crew relative to the digital thermometers.

b. Velometer. The velometer, used to obtain random, spot measurements of air flows throughout the OA, operated satisfactorily throughout the SL-3 and SL-4 missions with no difficulties or problems reported by the crews. Airflow measurements obtained indicated air flow rates of less than two feet per minute within the OA interior, and greater than 95 feet per minute immediately adjacent to air diffuser outlets.

c. Sound Level Meter/Frequency Analyzer. On Mission Day 7 (DOY 151) of the SL-1/2 missions the Skylab Commander obtained the M487 sound level meter, the frequency analyzer, three batteries, and connecting hardware from Locker W749 and commenced the performance of FO No. 7 (per Checklist Item 1A). After inserting the batteries and mating the sound level meter and the frequency analyzer, the Commander reported that he had experienced difficulty calibrating the assembled unit. He reported that he was unable to obtain the correct "K" factor adjustment (0.9). The maximum reading obtained was 0.7. Upon ground direction he obtained sound level measurements throughout the OA; a constant reading of 20 decibels was obtained.

The following day (DOY 152) the crew reviewed the M487 calibration checklist item and performed a second calibration attempt.

That time, the correct "K" factor adjustment value (0.9) was obtained. Measurements obtained throughout the OA indicated sound levels at or near 55 decibels. The difficulty experienced on the previous day was attributed to a procedural error.

Following assembly and calibration of the sound level meter and frequency analyzer by the SL-3 and SL-4 crews, the combined instruments were again used to obtain measurements of the OA sound levels within varying sound frequency bands. Measurements indicated an average sound level of 50 decibels at selected locations. The sound level meter/frequency analyzer assembly operated satisfactorily with no difficulties or problems reported by either the SL-3 or SL-4 crews.

d. Ambient Thermometers. The ambient thermometers were used throughout the SL-3 and SL-4 missions to obtain operational measurements of the ambient temperatures at selected locations throughout the OA. No difficulties or problems associated with the ambient thermometers were reported by the crews.

e. Force Gauge Assembly. The M487 force gauge assembly, used to obtain measurements of "push-pull" forces, was used during the SL-3 mission in an attempt to calibrate the Experiment T013 force measuring unit (FMU) No. 2. The force gauge assembly was used during the SL-4 mission to obtain "push-pull" forces required to actuate and retract the advance/shutter lever on the Experiment S019 spectrograph assembly. No problems or difficulties were reported by either crew during use of the M487 force gauge.

5. <u>Experiment Interfaces</u>. The experiment interfaces performed satisfactorily during the missions.

6. <u>Return Data</u>. Data returned for postflight evaluation included on-board tape-recorded crew comments and responses to questionnaires and were periodically "dumped" to ground stations for subsequent delivery to the PI. The M487 experiment photography was integrated throughout the 400-ft. film cassettes returned following each mission. Appropriate scenes were retrieved through editing of each mission's total film return.

7. <u>Anomalies</u>. No anomalies were identified during the three Skylab missions.

D. Experiment T002 - Manual Navigation Sightings

Two Principal Investigators are responsible for Experiment T002. Mr. Robert J. Randle, NASA Ames Research Center (ARC), was concerned with the mid-course navigational aspects, and Lt. Col. Stanley W. Powers, U.S. Air Force Academy, was concerned with orbital navigation. The experiment hardware was developed by ARC and by the Kollsman Corporation, Syosset, New York, under contract to ARC.

1. Experiment Description

a. Objectives. One T002 objective was to determine the crewman's reliability to obtain data from a hand-held sextant during extended weightless periods using mid-course navigation sightings. The other objective was to evaluate an orbital navigation method using a hand-held stadimeter and the sextant. Data from this experiment can be extrapolated to estimate crewmen's general ability for long weightless periods to perform tasks that require dexterity and judgment.

b. Concept. A series of 34 celestial observations on each mission were to be performed to accomplish these objectives, (see table IV-5). Each performance was to consist of 10 to 15 sightings. The mid-course sightings would consist of measuring the angles between stars, between a star and the moon, and between opposite moon edges. These last two measurements would provide navigational information because the angles measured are dependent upon spacecraft position. Orbital sightings would include two types: one using a stadimeter to measure the curvature of the earth's horizon as an indication of spacecraft altitude, and the other using a sextant to measure the angle between a star and the earth's horizon. These orbital sightings were to be combined into an operational sequence.

TABLE IV-5 TYPES OF T002 OBSERVATIONS

Targets Used	Instrument Used	Observation Type	Planned Number of Performances (each mission*)
Star to Star	Sextant	Mid-Course	6
Star to Moon	Sextant	Mid-Course	12
Across Moon	Sextant	Mid-Course	6
Earth Horizon	Stadimeter	Orbital	2
Star to Horizon	Sextant	Orbital	3
Combined Operational Sightings (Horizon, and Star to Horizon)	Stadimeter/Sextant	Orbital	5

* Note: performance of T002 was authorized for two missions, SL-3 and SL-4.

c. Hardware Description. The two optical instruments used during the experiment were a sextant (figure IV-8) and a stadimeter (figure IV-9).

The sextant was similar to a common marine sextant, and was the same type as used in the Gemini program, with minor modifications. It was used to measure angles between celestial bodies with readout markings every thousandth of a degree.

The stadimeter was used to observe a segment of the earth's horizon curvature and measure the angle between the lines of sight from the observer to the arc center and the chord center. A split optical display was provided whereby reference points could be located on the observed horizon and optically aligned by a manual control. The manually operated concentric control knob permitted readout of the measured angle. The spacecraft altitude could then be determined from the angle measured and the planet's diameter.

Three additional components assisted in experiment performance. These were: a collapsible hood for arrangement over the wardroom window preventing internal lighting reflections (figure IV-10); a stowage locker cushion (figure IV-11) protected the instruments from launch loads and provided in-orbit storage; and a battery transfer case facilitated resupply of the instrument illumination batteries.

2. Experiment Operation

a. Summary. T002 was not planned or operated on SL-1/SL-2. It was planned for operation on SL-3 and SL-4, at the convenience of the crew and on a non-interference basis with the other experiments. During SL-3, the experiment was performed 32 times and during SL-4 it was performed 25 times. An experiment performance summary is shown in table IV-6.

b. SL-3 Operation. Experiment performances were fewer than planned, because of low experiment priority. Mid-course sighting data indicated satisfactory hardware performance through the 49th day (DOY 257), the last T002 operation during SL-3. Orbital sighting data indicated satisfactory hardware operation although the earth's diffuse and non-uniform horizon resulted in lower quality data than desired. These horizon characteristics resulted in deleting the combined SL-4 operational sightings.

c. SL-4 Operation. High negative beta angles limited the orbital sighting opportunities from the wardroom window. For example, only one period (7 days long) occurred when the night earth horizon was visible from the wardroom window. Moon sightings were limited by the large beta angles and by the viewing opportunities available during the mission span. Specifically, launch occurred just after an opportunity

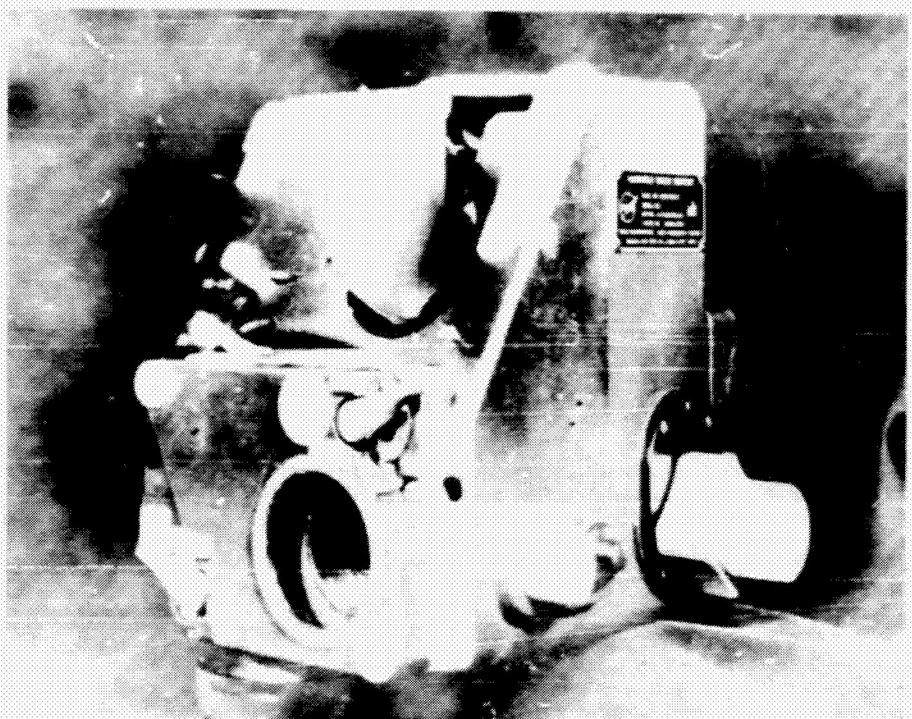

FIGURE IV-8 T002 SEXTANT

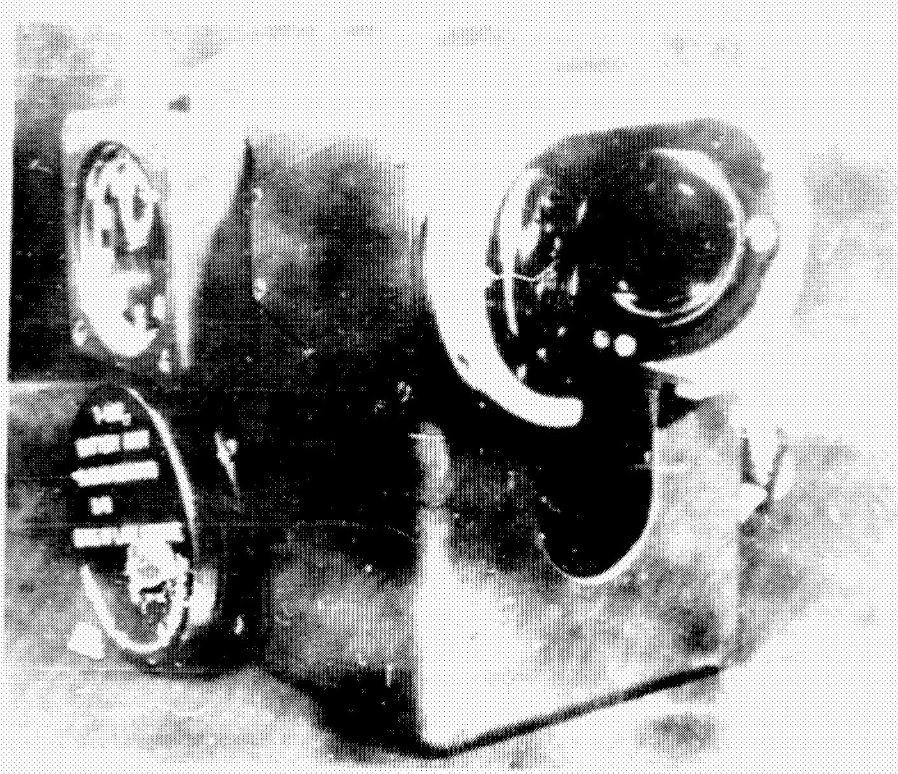

FIGURE IV-9 T002 STADIMETER

FIGURE IV-10 T002 COLLAPSIBLE HOOD INSTALLED AT WARDROOM WINDOW

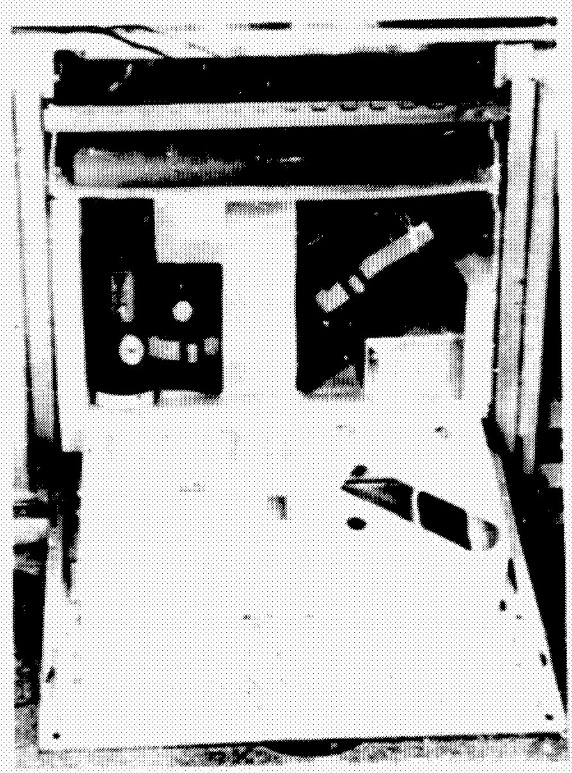

FIGURE IV-11 INSTRUMENT STORAGE CUSHION, BATTERY TRANSFER CASE, COLLAPSIBLE HOOD

TABLE IV-6 T002 PERFORMANCE SUMMARY

Targets	SL-3		SL-4	
	Planned	Accomplished	Planned	Accomplished
Mid-Course Sightings				
Star to Star	6	6	6	13
Star to Moon	12	10	12	5
Across Moon	6	6	6	3
Orbital Sightings				
Earth Horizon	2	3	5	4
Star to Horizon	3	3	5	0
Combined Operational Sightings	5	4	Deleted	
Total	34	32	34	25

and re-entry occurred at the start of another opportunity. Thus only two lunar viewing periods existed during almost three months in orbit. Crew assignments to other tasks resulted in 25 experiment performances.

All SL-4 mid-course sightings (except the last two sessions) produced unusable data because of a procedural deviation. This item required removal of the wardroom window transparent protective shield prior to performing T002. Sightings through this shield resulted in large biases and large standard deviations, demonstrating the need for a high-quality optical window. The last two mid-course sightings, performed with the protective shield removed, did show that nominal biases and nominal standard deviations could be achieved. The last T002 operation was on the 69th day (DOY 023). Stadimeter measurements were partially degraded by the wardroom window protective shield; however, most of this effect was masked by the diffuse, non-uniform horizon characteristics.

3. Experiment Constraints. All experiment constraints were satisfied except that during SL-4 all performances occurred in the last half of the mission. MRD Performance Conditions stated that they were to be distributed equally in time throughout the mission or half the operations were to be in the first half of the mission and the remainder in the second half. This distribution was to provide a measure of the crewman's proficiency change. This constraint was not

met due to crew activity on other tasks and resulted in loss of statistical proficiency variation data.

4. Hardware Performance. Experiment hardware performed satisfactorily on Skylab and is suitable for laboratory type, experimental missions. For example, it is usable for an orbital test of irradiance (that is, the tendency of a bright, extended surface, against a dark background to appear larger than actual). However, Skylab operations indicated that improvements in experiment hardware would permit easier manual operation and greater precision (measurement reliability) for emergency and long-duration interplanetary missions. These improvements are:

a. It was reported during both missions that the instrument adjustment knobs could be bumped or jarred upon release, causing a measurement indication shift. This could be minimized by redesign or new approaches, which could include a technique for rapidly and precisely resetting the instrument to a new angle, while providing for fine adjustments.

b. During both missions the crew reported difficulty in locating a specific star in the sextant field-of-view (FOV). A variable FOV could alleviate this difficulty, provided other constraints of a hand-held instrument such as size and weight could be met. A wide FOV eases star identification and a narrow FOV improves precision.

c. SL-3 crewman reported stadimeter stray light leakage. Postflight crew debriefing established that the light source was external to the instrument. This was not pursued further for Skylab.

d. It was reported during SL-3 that a battery discharge occurred when instruments were stored with the reticle light on. Power should be obtained from the spacecraft and disconnected during storage, thus eliminating all problems of special batteries.

e. While the voice recording technique for recording timing measurements proved accurate, navigational applications could use direct input to a computer. For manual emergency or back-up applications, a mechanical stopwatch and wristwatch timing technique (as proposed for operational sightings) could be used. One crewman suggested a digital time display in the FOV to be frozen at the instant of measurement. Also suggested was a modification to include the data display in the instrument FOV to avoid readaption of the operator's vision for subsequent sightings and readings.

f. The wardroom window hood was reported to be effective and necessary in reducing reflected glare, but awkward to handle. A shield or partition integrated into the spacecraft could provide a better operational situation.

5. Experiment Interface. All interfaces proved satisfactory.

6. Return Data. No physical data was returned to earth. All experiment data was contained in voice recordings. Magnetic tape recordings and voice transcripts have been supplied to the PIs. These voice transcripts proved adequate, although a more complete experiment performance could have been obtained with real-time dialogue between the experimenter and the operator. Housekeeping telemetry and SKYBET data have been supplied to the PIs.

7. Anomalies. No anomalies occurred in hardware operation.

E. Experiment T003 - In-Flight Aerosol Analysis

The Principal Investigator for Experiment T003 is Dr. William Z. Leavitt, U. S. Department of Transportation, Transportation Systems Center, Cambridge, Mass., which was the Hardware Developer.

1. <u>Experiment Description</u>

a. Objectives. The objectives were to: measure the spacecraft aerosol particulate matter concentration and distribution during each Skylab mission as a function of time and location; and return the collected aerosol particles and the logged data for postflight analysis.

b. Concept. Numerous investigations have been made into various optical methods of counting and sizing small aerosol particles having unknown indices of refraction. The Skylab instrument was to utilize an optical detection system which would identify particles essentially by size alone.

The instrument was to detect and count minute particles and identify particle size in ranges. The detector output signals were to consist of electronic pulses, related in amplitude to particle size. Each signal was to be directed into one of three registers, depending on the pulse amplitude. Each register was to indicate the number of accumulated particles in a selected size range. With a fixed known air flow through the instrument and a fixed counting time, each register's accumulated count could be calibrated to give the volumetric particle concentration of the corresponding size interval in the sampled atmosphere.

c. Hardware Description. The aerosol analyzer (AA), (see figure IV-12) a multi-channel, battery-operated, particle counter, was capable of sorting aerosol particles larger than one micron into three size groups: 1 to 3 microns, 3 to 9 microns, and 9 to 100 microns. The counter results were displayed at 8-second intervals for each of the three channels. The instrument contained a particulate collection system, so that postflight analysis could ascertain particle shape and composition.

The experiment equipment (figure IV-13) and functions are:

Experiment Hardware	Function
Aerosol analyzer stowage container	To house the AA, the filter insert container assembly, log cards and clips.

All dimensions in inches

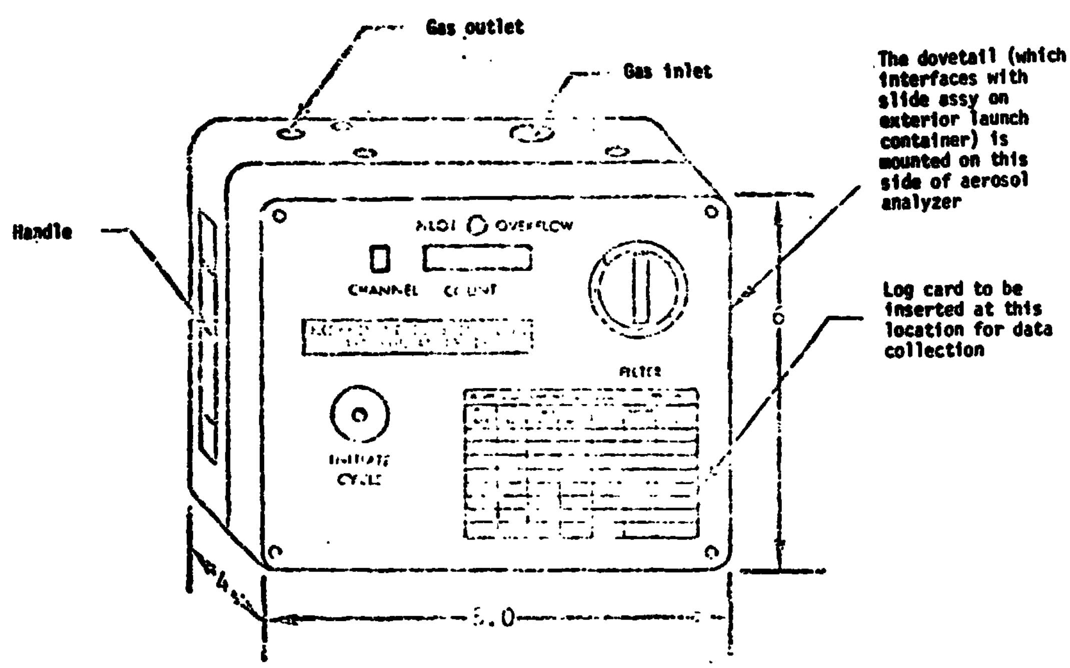

FIGURE IV-12 AEROSOL ANALYZER

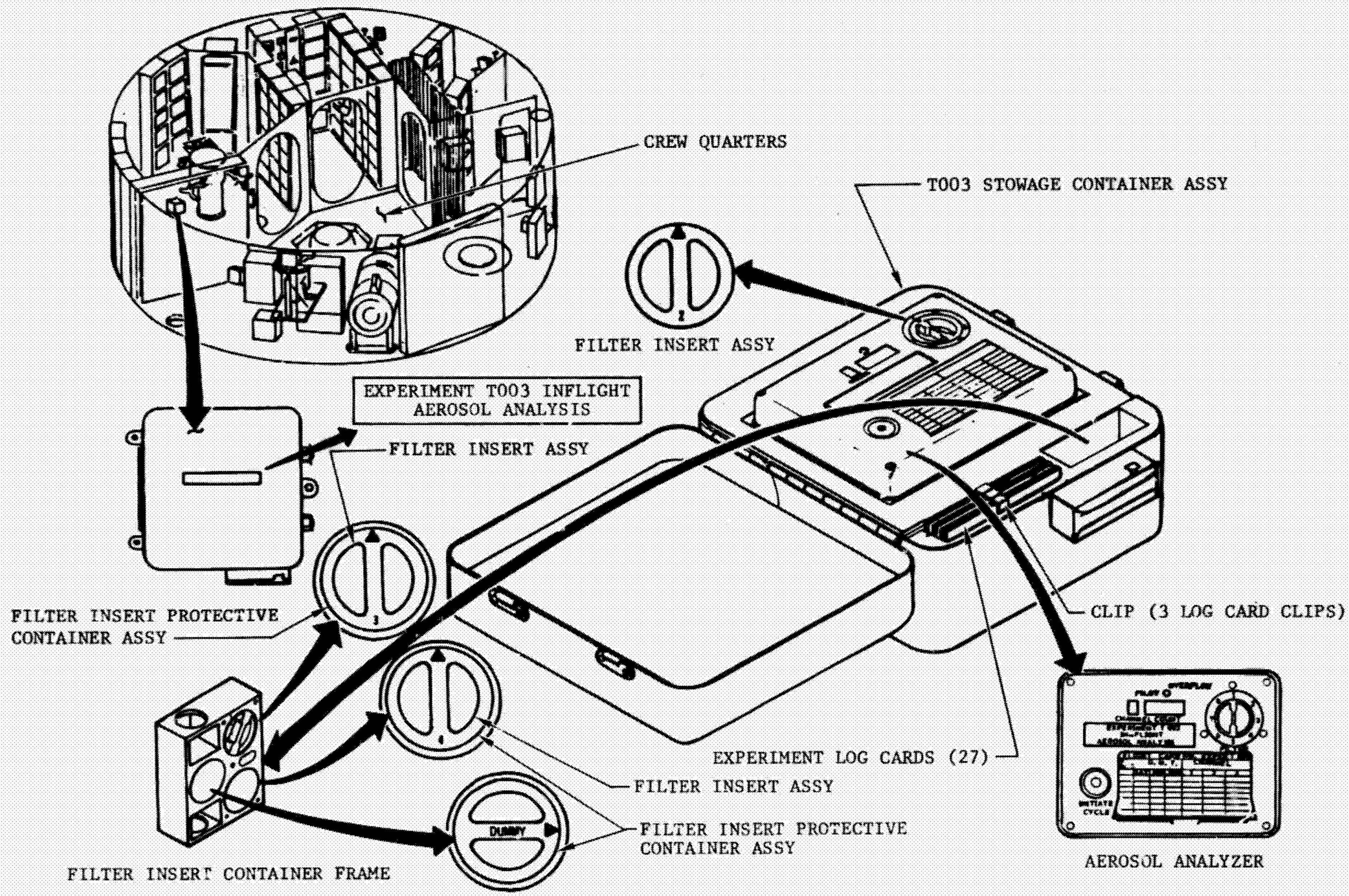

FIGURE IV-13 T003 EXPERIMENT EQUIPMENT

Experiment Hardware	Function
Aerosol analyzer	The AA consisted of four subsystems; the pneumatic subsystem, the optical subsystem, the filter subsystem, and the electrical/electronic subsystem. Air drawn into the AA by the pump passed first through an illuminated sampling volume. A selected portion of the light scattered by each aerosol particle (30° to 53° angle, complete cone around the optical axis) was detected by a photomultiplier tube (PM), causing a PM pulse signal which is related in amplitude to the scattered particle size. The pulses were sorted into three discrete amplitude intervals and the count accumulated in each interval during the sampling time, which commenced automatically after an initial purging period. At the end of the display period, the AA shut itself off. The AA was designed to operate without saturation in atmosphere containing several million particles per cubic foot, which was far greater than the particulate concentration in the spacecraft. There were no inputs other than the air intake. The AA output was a display identifying the channel indicating particle size range, the number of counts, and the occurrence of an overrun if the count exceeded 9999 on a channel.
Filter insert container frame	To house the filter insert protective container assemblies.
Filter insert protective container assemblies	To house the AA filter insert assemblies and the dummy filter insert assembly.

Experiment Hardware	Function
	NOTE: The filter inserts (in their protective containers) were returned to earth at the conclusion of each mission.
Filter insert assemblies	To collect the measured aerosol particles for postflight analysis.
Dummy filter insert assembly	To keep the empty filter insert protective container assembly free from possible contamination prior to and during launch, during experiment operation, and also between flights. Was installed in AA at the conclusion of SL-4.
Log cards and clips	Log card to be placed on face of AA and used to record the following experiment data: Filter position, GMT (day, hour, min) and the number of particles counted (as displayed in each channel). NOTE: The log cards and clips were returned to earth at the conclusion of each mission.

2. Experiment Operation. The AA was operated on all Skylab missions. Daily measurements were made at the stowage location as well as other periodic measurements taken at designated locations throughout the spacecraft. (Refer to figure IV-14.) Table IV-7 lists all experiment operating locations and associated crew station numbers, as well as the corresponding filter selector numbers related to these operating locations.

Crew tasks associated with the measurements were arranged and categorized into Functional Objectives (FOs). The FOs were scheduled into the crew's daily flight plan. The number assignment, description, and status of each FO are shown in tables IV-8, IV-9, and IV-10 for each mission. All measurement results were recorded on the experiment log cards.

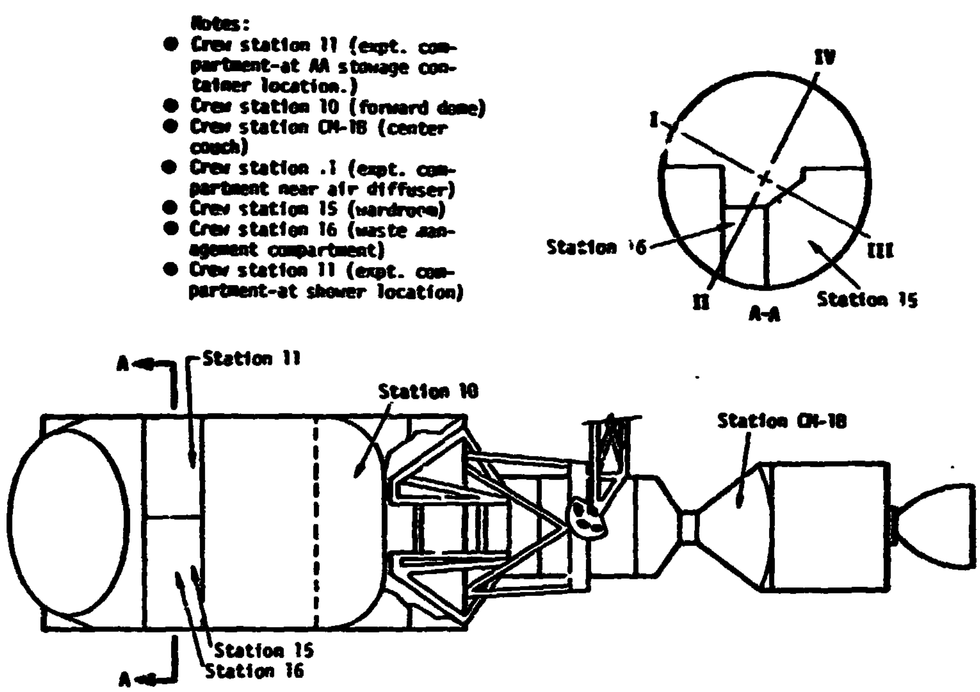

FIGURE IV-14 MEASUREMENT STATIONS FOR AEROSOL ANALYZER

TABLE IV-7 EXPERIMENT T003 MEASUREMENT LOCATIONS AND FILTER POSITION NUMBERS

AA Filter Selector Number	Crew Station Number	Experiment Operating Locations
1	CS-11	Crew quarters at AA stowage container location.
2	CS-10	Center of AM/OWS hatch.
3	CS-CM-1B	Command module (CM) center couch.
4	CS-11	At air diffuser in floor of crew experiment area, adjacent to trash disposal in experiment compartment.
5	CS-15	In wardroom above table.
6	CS-16	In waste management compartment at intercom on wall.
7	CS-11	Crew quarters (at shower location).
8	---	At the astronauts' discretion.

TABLE IV-8 SKYLAB MISSION SL-1/2 FUNCTIONAL OBJECTIVES

FO	DESCRIPTION	STATUS
1	As soon as practical (but not later than 5 days) after OWS activation, the experiment will be performed at CS-11 (crew quarters at expt stowage location); CS-10 (center of AM/OWS hatch); CS-1B (CM center couch); CS-11 (crew quarters near air diffuser); CS-15 (wardroom), and CS-16 (head).	FO-1 was initiated on MD 4. Portions of this FO were successfully completed.
2	Upon completion of FO 1, the AA will be returned to the storage location and subsequent readings at CS-11 (crew quarters at AA stowage container location) will be taken every 8 (± 2) hours thereafter.	57 readings (of the scheduled 69) were successfully completed.
3 and 4	On the 10th day after the measurements for FO 1, AA readings will be taken for FO 3 at CS-10 (center of AM/OWS hatch); CS-1B (CM center couch) and CS-11 (crew quarters near air diffuser) immediately after the regularly scheduled 8 (± 2) hour readings at CS-11 (crew quarters at AA stowage container location). On the 10th day after completing FO 3, the readings will be repeated for FO 4.	FO-3 Not accomplished FO-4 Successfully completed
5 and 6	On the 10th day after the measurements for FO 1, AA readings will be taken for FO 5 at CS-15 (wardroom) before food preparation and also after meals; at CS-16 (head) immediately before use of the sanitary facility and also after weighing of the wet fecal sample bag.	FO's 5 & 6 Portions of these FO's were successfully completed.
7,8 & 9	Operate the AA at CS-11 (crew warters at shower location) immediately after doffing clothes in preparation for shower, on three shower occurrences.	FO's 7 & 8 Successfully completed FO-9 Not accomplished
10	At the astronauts' discretion, up to 20 readings will be made during the flight at times and positions the astronaut feels may be a source of particulate generation.	Not accomplished

TABLE IV-9 SKYLAB MISSION SL-3 FUNCTIONAL OBJECTIVES

FO	DESCRIPTION	STATUS
1	As soon as practical (but not later than 5 days) after OWS activation, the experiment will be performed at CS-11 (crew quarters at expt stowage location); CS-10 (center of AM/OWS hatch); CS-1B (CM center couch); CS-11 (crew quarters near air diffuser); CS-15 (wardroom); and CS-16 (head).	FO-1 was initiated on MD7 and successfully completed on MD8.
2	Operate the AA to obtain periodic readings in the stowage location in the crew quarters during the presleep and postsleep periods commencing with the first sleep period after performing FO 1.	60 readings (of the scheduled 112) were successfully completed
3 thru 7	Operate the AA to obtain readings at CS-10 (center of AM/OWS) hatch); CS-1B (CM center couch); and CS-11 (crew quarters near air diffuser) every 10 ± 1 days after FO 1.	<u>FO's 3 & 5</u> Portions of these FO's were successfully completed <u>FO's 4, 6 & 7</u> Successfully completed
8 thru 12	Operate the AA to obtain readings at CS-15 (wardroom) before food preparation and also after meals, and CS-16 (head) immediately before use of the sanitary facility and also after weighing of the wet fecal sample bag, every 10 ± 1 days after FO 1.	<u>FO's 8 & 10</u> Successfully completed <u>FO's 9 & 11</u> Portions of these FO's were successfully completed <u>FO-12</u> Not accomplished
13 thru 19	Operate the AA at CS-11 (crew quarters at shower location) immediately after doffing clothes in preparation for shower, on seven shower occurrences.	<u>FO-13</u> Successfully completed <u>FO's 14 thru 19</u> Not accomplished
20	At the astronauts' discretion, up to 20 readings will be made during the flight at times and positions the astronaut feels may be a source of particulate generation.	Six measurements (out of a maximum 20) were successfully completed

TABLE IV-10 SKYLAB MISSION SL-4 FUNCTIONAL OBJECTIVES

FO	DESCRIPTION	STATUS
1	As soon as practical (but not later than 5 days) after OWS activation, the experiment will be performed at CS-11 (crew quarters at expt stowage location); CS-10 (Center of AM/OWS hatch); CS-1B (CM center couch); CS-11 (crew quarters near air diffuser); CS-15 (wardroom); and CS-16 (head).	FO-1 was initiated on MD4 and successfully completed on MD5
2	Operate the AA to obtain periodic readings in the stowage location in the crew quarters during the presleep and postsleep periods commencing with the first sleep period after performing FO 1.	144 readings (of the scheduled 156) were successfully completed
3 thru 9	Operate the AA to obtain readings at CS-10 (center of AM/OWS hatch); CS-1B (CM center couch); and CS-11 (crew quarters near air diffuser) every 10 $\pm$ 1 days after FO 1.	FO's 3 thru 7, & 9 Successfully completed FO-8 Not accomplished
10 thru 16	Operate the AA to obtain readings at CS-15 (wardroom) before food preparation and also after meals, and CS-16 (head) immediately before use of the sanitary facility and also after weighing of the wet fecal sample bag, every 10 $\pm$ 1 days after FO 1.	FO's 10, 11, & 13 Successfully completed FO's 12, 14, & 16 Portions of these FO's were successfully completed FO-15 Not accomplished
17 thru 25	Operate the AA at CS-11 (crew quarters at shower location) immediately after doffing clothes in preparation for shower on nine shower occurrences.	FO's 17 thru 20, 22 & 23 Successfully completed FO-21 Portion of this FO successfully completed FO's 24 & 25 Not accomplished
26	At the astronauts' discretion, up to 20 readings will be made during the flight at times and positions the astronaut feels may be a source of particulate generation.	5 measurements (out of a maximum 20) were successfully completed

The crew experienced no difficulties in performing the experiment objectives during any Skylab mission.

3. Experirent Constraints. All erperiment constraints were satisfied

4. Hardware Performanc. `` AA operated successfully on 24 consecutive days of the scheduleo y mission (SL-1/2), on 49 days of the scheduled 59-day mission (SL-3), ..d on 80 consecutive days of the scheduled 85-day mission (SL-4). A total of 390 measurements (of the scheduled 538) were taken. (Refer to table IV-11.) The crew's comments pertinent to the operation, performance, and handling of the experiment hardware were consistently favorable.

5. Experiment Interfaces. All experiment interfaces were satisfactorily met.

6. Return Data. There were two types of returned data: the flight-assigned filter insert assembly and the annotated log cards. (Refer to table IV-12.)

7. Anomalies. No anomalies or problems were identified during any Skylab mission.

TABLE IV-11 EXPERIMENT T003 MEASUREMENT SUMMARY

Skylab Mission	Measurements Scheduled	Measurements Taken
SL-1/2	114	73
SL-3	182	106
SL-4	242	211
SL-1/2, 3, & 4	538	390

TABLE IV-12 RETURNED DATA AND QUANTITIES

Mission	Returned-to-Earth Data and Quantities	
	Used Filters	Used Log Cards *
SL-1/2	1	5 *
SL-3	1	7 *
SL-4	1	13 *

* A total of 25 used log cards (out of the 27 launched) were returned to earth.

F. Experiment T013 - Crew Vehicle Disturbances

The Principal Investigator for Experiment T013 is Mr. Bruce A. Conway, NASA Langley Research Center, Hampton, Virginia. The Hardware Developer was Martin Marietta Aerospace, Denver, Colorado.

1. Experiment Description.

a. Objectives. The objectives were: to measure the effects of various crew motions on the manned spacecraft dynamics (specifically the torques, forces, and vehicle motions produced by the astronaut's body motions); to verify information obtained from ground simulation experiments; and to determine the astronaut motion effects on the vehicle attitude and control.

b. Concept. The concept was to utilize applied-force measuring devices and continuous body-limb position indicators attached to the crewmen in conjunction with existing spacecraft pointing and attitude control systems. The crewmen were to perform specific and time-correlated tasks which were to impact the spacecraft pointing and attitude control systems.

c. Hardware Description. Astronaut body motion was measured by the limb motion sensing assembly (LIMS), which consisted of a skeletal structure incorporated into a flight type suit, with major body joint pivots (see figure IV-15). Each pivot was monitored by a linear potentiometer which provided a continuous measurement of body limb position as the subject astronaut performed the assigned task. Two 16mm data acquisition cameras (DAC) provided on-board motion picture photography.

A force measuring system (FMS), consisting of two force measuring units (FMUs) attached to the OWS walls (see figure IV-16), was used to measure the forces and moments applied to the OWS structure during the crewmen's assigned movements. Figure IV-17 shows the limb stowage container which protected the LIMS from launch vibration environment.

The LIMS and FMS measurement data was processed and telemetered with the real-time transmission of the applicable ATM pointing control system data to the ground.

The experiment data system (EDS) (see figure IV-15) converted the LIMS and FMS analog signals to a serial digital wave train and routed the data to the Airlock Module (AM) experiment tape recorder. The AM timing signal was routed to the EDS to provide data timing correlation. The EDS was mounted on the experiment compartment floor between FMUs No. 1 and 2.

FIGURE IV-15 LIMB MOTION SENSING ASSEMBLY (LIMS) WITH EXPERIMENT DATA SYSTEM

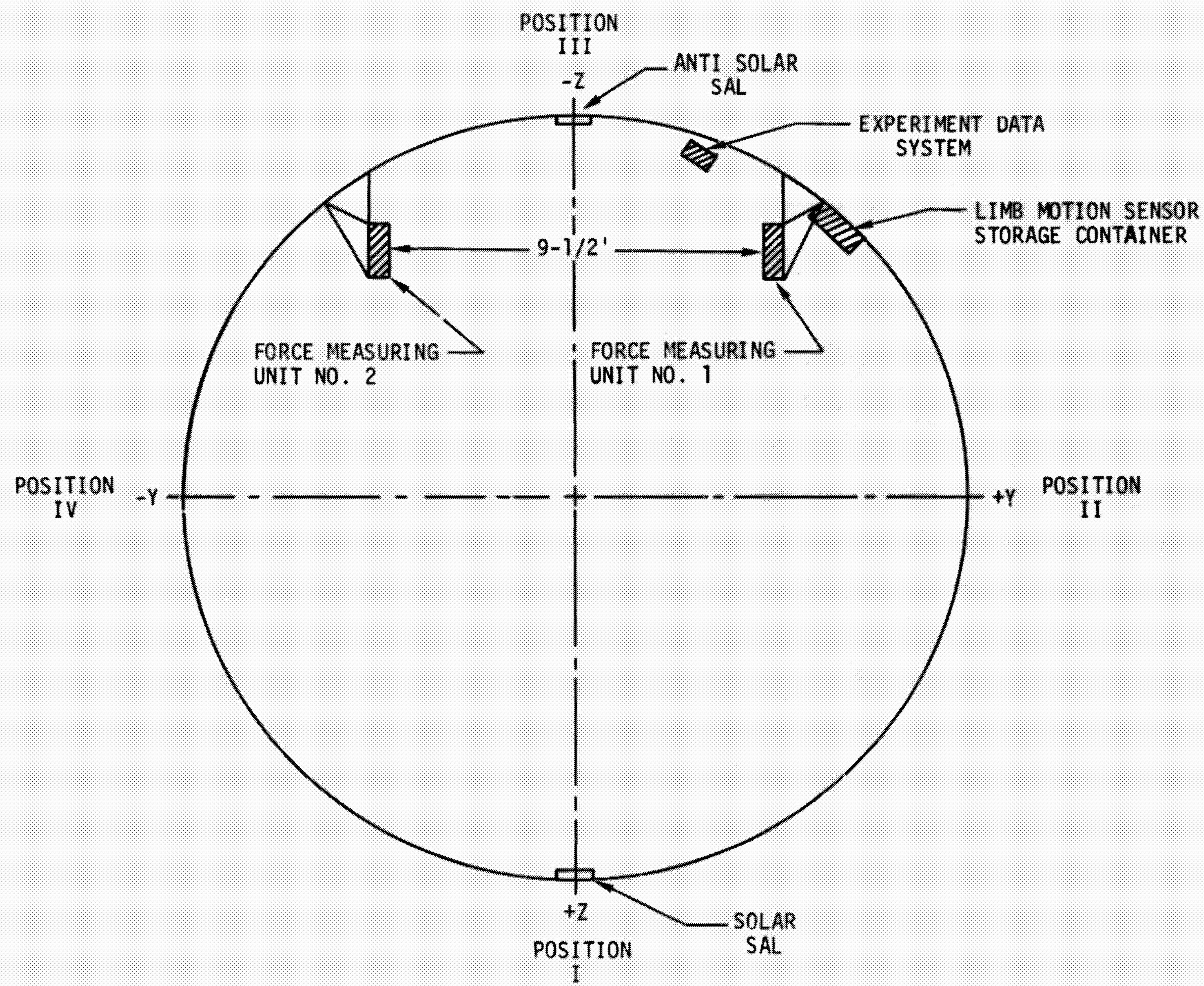

FIGURE IV-16 TO13 HARDWARE LOCATION IN OWS FORWARD COMPARTMENT

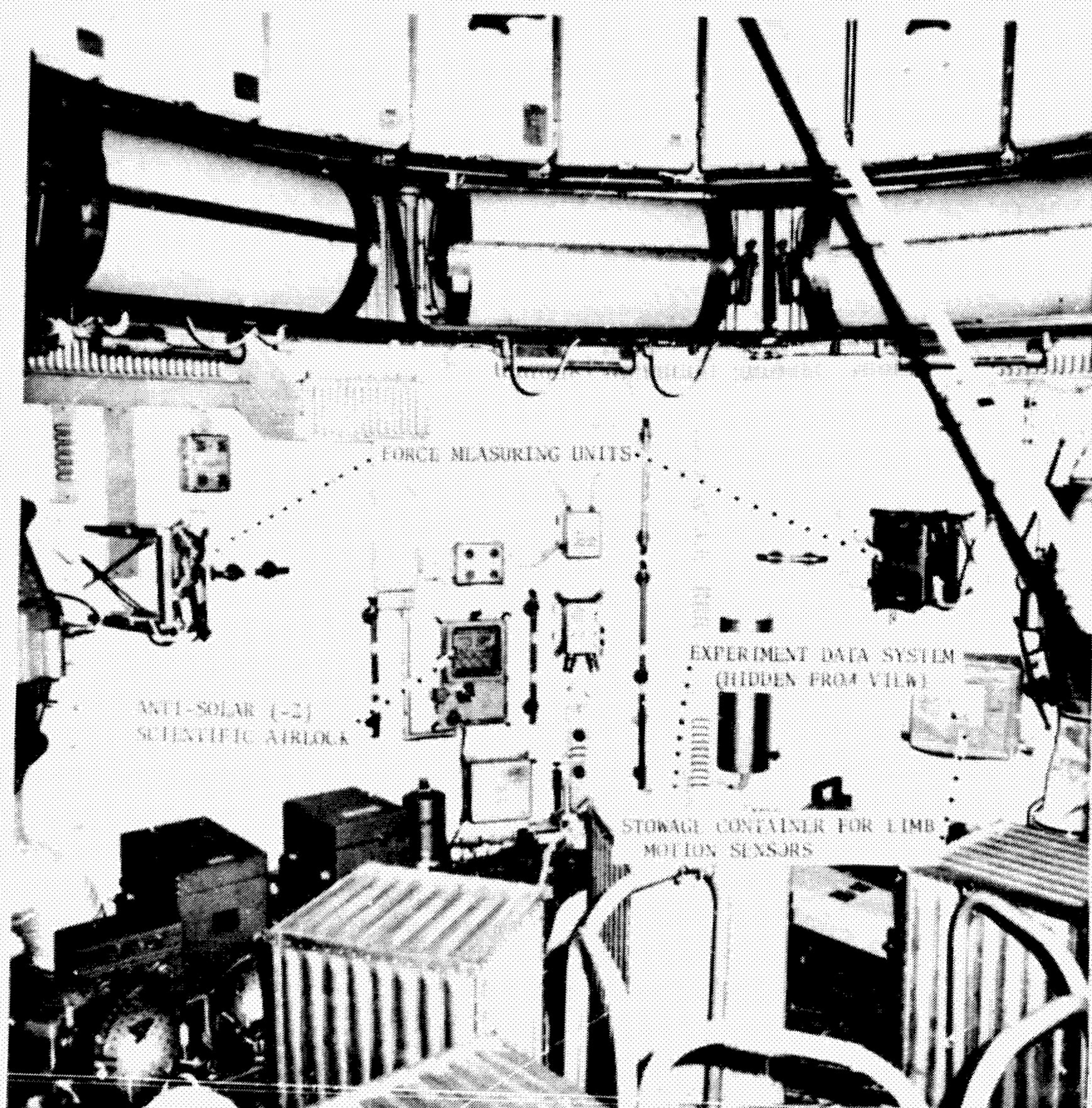

FIGURE IV-17 EXPERIMENT T013 FLIGHT HARDWARE INSTALLED FOR LAUNCH

2. Experiment Operation. Experiment T013 was not scheduled for operation on SL-1/SL-2. Several groups desired the information from T013 (i.e., ATM experiments; ATM attitude pointing and control systems; and ATM experiment pointing and control systems). There were several meetings and working sessions to assure performance early during the SL-3 mission. The experiment operation was generally successful. A complete operation summary is presented in table IV-13. Experiment activities are discussed below:

a. Pre-operational checkout. The experiment systems were checked out on DOY 226. All systems (other than the limb motion sensor) were activated and were nominal.

b. Operation. The experiment was activated and operated on DOY 228. The tasks included: experiment set-up by the Commander; conducting task 3 over ground station Vanguard; conducting tasks 1 and 2; and repeating tasks 3, 1 and 2. Task definitions are presented below:

Task 1. Gross body motions - The following motions were performed while the subject was constrained to FMU No. 1: right and left arm and leg motions, torso motions, breathing, sneezing and coughing.

Task 2. Simulate console operations - The subject simulated the flipping and rotating of control panel switches while restrained to FMU No. 1.

Task 3. Worst case inputs - The Commander performed rapid arm and leg movements, and soared between the FMUs. The Pilot joined the Commander in performing soaring maneuvers in unison. The Pilot soared between the food locker and film vault.

Crew comments indicated that the experiment was straightforward and no operational problem was encountered. They did not successfully operate the DACs during the task 3 sequence. Their comment was that they did have the television camera "ON" and they indicated they did rerun task 3 with the DACs on, but this sequence was not performed over a ground tracking station. The PI proposed running another task 3 without requiring the astronaut to don the limb motion sensor garment. This task was approved by the Flight Management Team (FMT) and was performed on DOY 242. A review of downlink telemetry indicated that an anomaly had occurred on FMU No. 2. The FMU load cells No. 4 and 5 went off scale high during the "worst case input."

c. FMU No. 2 malfunction procedure. A malfunction procedure was performed by the crew on DOY 240 to ascertain if the FMU No. 2 anomaly was purely mechanical. The procedure included a recalibration of FMU No. 2, utilizing the M487 force gauge. The astronaut was instructed to push the gauge into the FMU sense plate center and

TABLE IV-13 T013 EXPERIMENT OPERATIONS ON SL-3

Mission Day	GMT	Experiment Operations	Description	Anomaly	Summary
18 (DOY 226)	1320 to 1330	Pre-operational checkout	Force measuring units and experiment data system were activated	None	Nominal operations
20 (DOY 228)	1525 to 1645	Operation	Tasks included: o Set-up o Task 3 (Over Vanguard) o Task 1 o Task 2 o Task 3 o Task 1 o Task 2	No camera activation over Vanguard Malfunctioning load cells at 15:33:58	Must rerun a task 3 to obtain the camera coverage over ground tracking station Load cells 4 & 5 of FMU No. 2 remained off scale high Malfunction procedure to be implemented
32 (DOY 240)	1500 to 1510	Run malfuncion procedure on FMU No. 2, Load Cells 4 & 5	The astronaut was instructed to guage the load cells and try to pull the sense plate of the FMU to remove any mechanical binding that might exist.	None	Malfunction procedure not successful. Conclusion - not able to fix load cells; use analytical method to obtain useful data.

TABLE IV-13 TO13 EXPERIMENT OPERATIONS ON SL-3 (CONTINUED)

Mission Day	GMT	Experiment Operations	Description	Anomaly	Summary
32 (DOY 240) (cont.)			If it was a mechanical malfunction, this procedure might correct it. Also the M487 Force Gauge was used to recalibrate the FMU for analytical study.		Some data handling problems experienced. PI to receive data from remote sites.
33 (DOY 241)	1515 to 1525	Checkout and Recalibration	For measuring system and experiment data system activated	None	Nominal operations
34 (DOY 242)	1510	Calibrate FMUs	Calibration	None	Nominal operations
	1600	Rerun task 3	Rerun task 3 due to the camera not being activated on MD20	EDS switch not activated	An oversight by the crewmen was found after completion of the run. EDS power switch was inadvertently shut "off". Another run required.
39 (DOY 247)	1300 to 1310	Rerun task 3	Due to EDS not being activated on M/D 34. Task 3 run over ground tracking station to accomplish FO-1 objectives	None	All systems nominal

to "mark" via voice communication when the gauge read 5, 10, 15, 20, 25, 30, 35, and 40 pounds; a 15 pound force, both a push and a pull, was applied to the sense plate edges. It may be possible from this test for the PI to obtain information from the remaining four load cells that would enhance his overall capability of defining the actual loads seen on that unit.

d. Checkout and recalibration. The experiment was recalibrated on DOY 241 before operating task 3 for the third time. The Commander performed additional calibrations. This has given the PI excellent data for analysis.

e. Re-run task 3 due to DAC not being activated. A re-run of the "worst case inputs" (task 3) was tried on DOY 242, but the T013 experiment data system was inadvertently turned OFF. The dump tape voice record indicated that the EDS POWER switch was turned OFF and no data was received from the experiment. A question was sent to the crew on this subject, but their response was that they were not sure. A re-run was requested to verify the problem was a procedural error.

f. Re-run task 3 due to experiment data system not being activated. After careful and thorough investigation of the experiment activation, the crew again performed task 3 on DOY 247. All systems worked nominally, other than the same two malfunctioning load cells on FMU No. 2. The experiment and housekeeping data were received and are being analyzed at Langley Research Center.

3. <u>Experiment Constraints</u>. The experiment constraints were successfully met during the mission.

4. <u>Hardware Performance</u>. The hardware performed excellently in accomplishing the experiment objectives. Although a malfunction occurred on load cells 4 and 5 of FMU No. 2, a work-around was performed to recalibrate the unit while in orbit. Additional calibration data was obtained and will be utilized during data analysis. It is possible that some quality data can be obtained from the remaining four load cells.

No problems were identified with the remaining hardware (FMU No. 1, limb motion sensor, LIMS stowage container and experiment data system). The experiment's objectives were completed although the experiment data system was inadvertently turned off during one run, and an "out of synchronization" timing signal necessitated obtaining one run from the ground station raw experiment data tape

Crew debriefing comments on T013 operation included: "Stowage and unstowage was simple and straightforward. No comments. The suit fit well. No remarks there". And, "it's easy to run, it's easy to rig out, and the cameras are easy to put in position and it is quite

easy to move back and forth between the FMUs. I thought that was going to be one hard thing pre-flight but it turned out to be one of the easier." The conclusion is that the astronaut experienced no major operational problems.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. The data other than telemetry, included 930 feet of S0168 colored film, voice transcripts, and crew log books.

7. Anomalies. The only anomaly that occurred was the FMU load cell malfunction. Langley Research Center conducted a failure analysis and the conclusions are discussed in the following:

The FMS was verified on DOY 226 with all systems nominal. FMU No. 2 load cells (4 and 5) were stressed during the DOY 228 performance of task 3 (worst case operations) such that their amplified output exceeded five volts and maintained this condition thereafter.

Possible causes for these permanent overscale readings are:

Mechanical binding or deformation of FMU component portions, such that a compressive preload was maintained on the two affected load cells;

Damage/bond failure between the semiconductor strain gage and the load cell beam.

A malfunction procedure was performed by the crew to ascertain whether the problem was purely mechanical. Preliminary data inspection from this malfunction test indicated inconclusive results. The two load cells remained in an overscale condition after the malfunction procedure was carried out. The other four load cells on FMU No. 2 exhibited a slight "zero" shift in their amplitude outputs, simultaneous with the offscale shifts in load cells 4 and 5. The "zero" shifts were permanent. The other four load cells continued to respond in a nominal manner.

Based on the data available from the T013 runs, it appears that the likely condition producing the load cell anomalies consisted of the astronaut applying a large bending torque to the FMU No. 2 sense plate during an impact, or landing from a free-soaring maneuver. The 6 load cell readings from FMU No. 2, during the half-second prior to the offscale values for load cells 4 and 5, indicated that a combined torque of approximately 24 ft/lbs was being applied in conjunction with a net force of 70+ lbs. This particular input could result, for example, by a combined pushing on the upper right corner and

pulling on the lower left corner; or it could be caused by a twisting input to the portable handhold mounted on FMU No. 2.

Forces as high as 70 lbs. were input to the sense plate during other portions of the T013 run. A force of this magnitude, if applied to the upper right corner, would cause offscale readings in the affected load cells.

The conclusion at this time, based on telemetry data, is that the overscale readings from FMU No. 2 load cells 4 and 5 were caused by applied forces and/or torques higher than the design measurement range for the T013 force measuring system. It is uncertain whether the failure of the readings to return to nominal values following removal of the applied loads was caused by mechanical deformation, strain gage bond failure, or FMU signal conditioner electrical failures (the latter being considered unlikely, since a double failure would be required to render two load cells unusable). However, since zero shifts were noted in load cells 1, 2, 3 and 6, indications are that mechnical deformation occurred. The return of one or both damaged load cells would have been desirable for a more complete failure analysis.

G. Experiment T020-Foot-Controlled Maneuvering Unit

The Principal Investigator for Experiment T020 is Mr. Donald E. Hewes, NASA Langley Research Center, Hampton, Virginia. The Hardware Developer was the Martin Marietta Aerospace, Denver, Colorado.

1. Experiment Description.

a. Objectives. The objective was to provide information pertaining to the design and use of an unstabilized experimental maneuvering device by conducting inflight and ground based evaluations. The information was to determine: 1) maneuvering abilities, 2) design parameters and other data applicable to future operational systems and 3) correlation between the flight test and the ground simulators.

b. Concept. The concept was to provide a relatively simple maneuvering system as an experimental test bed for use within the OWS and was not to be an operational prototype. The system was to provide a foot-controlled maneuvering unit leaving the astronauts' hands available for other tasks. It was to use compressed nitrogen as a propellant and have no provisions for automatic stabilization.

c. Hardware Description. The Foot-Controlled Maneuvering Unit (FCMU) provided support, a seat and crewman restraints and contained the thrusters and the foot-operated control devices. The thrusters were located below and outboard of the crewman's feet. The propellant effort was provided by ambient-temperature-compressed nitrogen gas supplied to the thrusters. The propulsion gas tank was contained within the backpack strapped to the crewman's back. The hardware is shown in the stowed and operational modes in figures IV-18 and IV-19 respectively.

2. Experiment Operation.

a. Skylab 1/2. Experiment T020 was neither activated nor operated on SL-1/SL-2. The propellant supply subsystem (PSS), used as a nitrogen gas source for experiments T020 and M509, was successfully activated on DOY 161.

b. Skylab 3. Experiment T020 was performed three times on SL-3. The CDR flew the FCMU in the shirtsleeve mode on DOYs 231 and 241, and in the pressure suited mode on DOY 256.

c. Skylab 4. A modification kit, containing rigidizing brackets and additional restraint straps, was launched on SL-4 for use in overcoming difficulties encountered during the SL-3 test runs. The first shirtsleeve mode was performed on DOY 15, using the rigidized system. A second shirtsleeve mode was performed on DOY 24 and evaluated both the rigidized and non-rigidized systems. The s[illegible]ed

mode was not accomplished due to the performance of a second shirt-sleeve mode and the shortage of available crew time.

The atmospheric management techniques employed prior to, during and following each operation were successful in controlling the

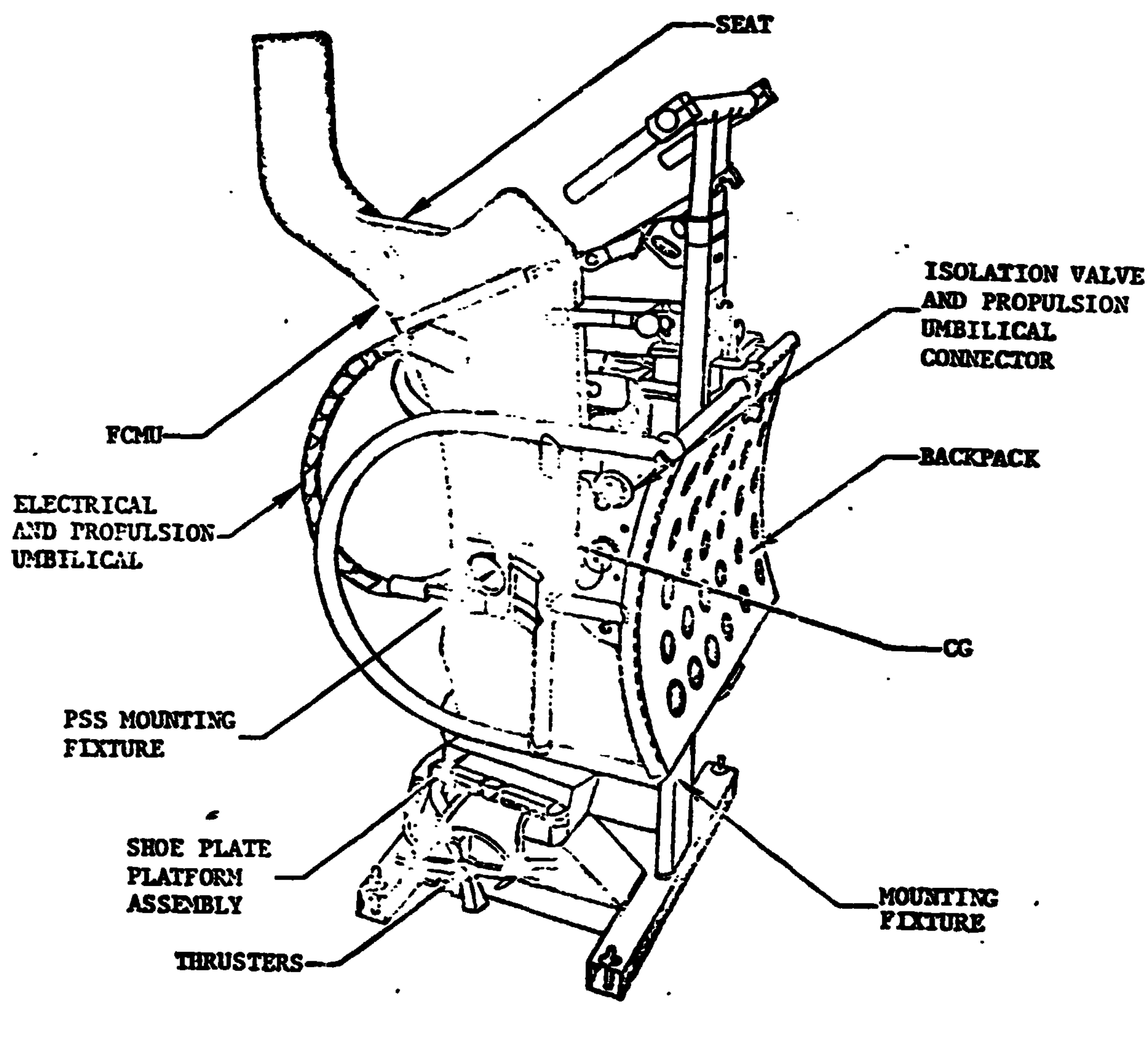

FIGURE IV-18. FCMU AND BACKPACK - STOWED CONFIGURATION

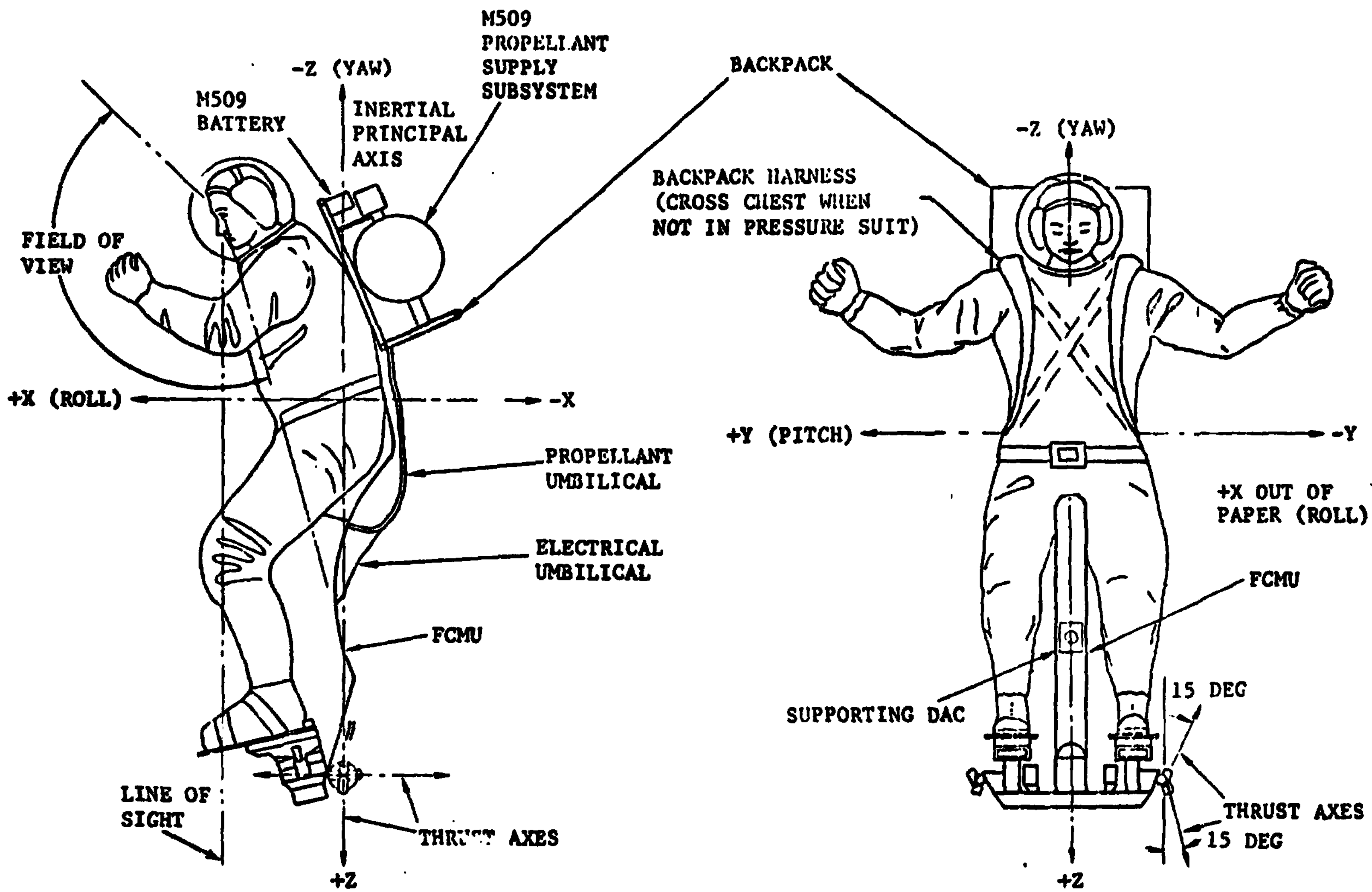

FIGURE IV-19. FCMU OPERATIONAL CONFIGURATION

OWS atmosphere partial pressure of oxygen levels and airflow velocities were within the desired limits.

3. Experiment Constraints. All experiment constraints were successfully met during the mission with the following exceptions:

a. Mission Rule 14-1, prohibiting experiment installation in the SAL during T020 operations, was violated. This violation was considered acceptable based upon a JSC safety study and real-time evaluation of the circumstances. No difficulties were encountered and the rule was deleted October 23, 1973.

b. The 16mm and 35mm, type S0168, film used for T020 photography was exposed to higher-than-predicted temperatures during the prehabitation and early manned phases of the SL-1/2 mission. The film returned on SL-4 showed very noticeable degradation but has been found usable from the data evaluation standpoint.

4. Hardware Performance. Experiment and related hardware performed adequately throughout the various test runs. Restraint harness loosening during the first run allowed relative motion between the subject, backpack and FCMU. The center of mass shift resulted in cross-coupling during translation and rotation maneuvers. Precise control inputs were difficult to achieve due to the FCMU movement between the subject's legs. These difficulties were moderated by an on-orbit modification during SL-3 and a modification kit launched on SL-4. The pneumatic and control systems performed without incident.

The performance of the component units is discussed individually in the following paragraphs.

a. Foot-controlled Maneuvering Unit. The FCMU performed well during the five test sequences, with no malfunctions reported. Several noteworthy items pertaining to the unit's performance are:

The crewman had difficulties keeping his feet in the foot restraints during the SL-3 suited run. He experienced an inadequate field-of-view in the foot direction. Evaluation of the returned photographs established that these difficulties were caused by improper harness adjustment which resulted in the crewman leaning back further than desired. The SL-4 crewman was unable to provide evaluation of this problem because the planned suited run could not be scheduled.

The SL-3 crewman reported that the control input forces seemed excessive for the situation. He noted that the forces were much higher than those used during normal day-to-day translations within the OWS. However, the SL-4 crewman considered the input forces satisfactory and within the range expected.

The SL-4 crewman experienced minor difficulty in commanding the left toe-up inputs and attributed this to a coordination problem, unique to himself, and accentuated by muscle tone changes due to 70 days in orbit.

b. Backpack. The backpack performed within its design limits and no problems were encountered. During checkout for the first run the crew reported that the solenoid valve was hot to the touch. It was verified on the ground that this was normal. Subsequently, the procedure were changed reducing the active time of the solenoid valve by expeditious manual shutoff valve use.

c. Harness. A loosening tendency in the restraint harness system securing the crewman to the hardware, caused difficulty during the first T020 test run on DOY 231. Temporary improvements were made using onboard restraint straps to supplement the harness. This improved harness system was used on the remaining SL-3 test runs on DOYs 241 and 256.

A modification kit, containing additional restraint straps and brackets for rigidizing the backpack to the FCMU, was provided for SL-4. The kit components were installed prior to the first SL-4 data run in the shirtsleeve mode. The resulting rigidized configuration, shown in figure IV-20, exhibited improved performance characteristics.

A second shirtsleeve run on SL-4 was performed to obtain additional data at the crewman's request. (Modification kit installation, preparation and checkout of the unit had required approximately one hour and fifteen minutes longer than predicted.) This second run included added data-take time with the rigidized system, followed by rigidizing bracket removal and evaluation of the resulting non-rigid system shown in figures IV-21 and IV-22.

d. Batteries. The rechargeable batteries used for T020 operations were exposed to excessive ambient temperatures during the pre-habitation phase of the SL-1/SL-2 mission. Subsequent testing and evaluation showed that the batteries had not been degraded and their use was approved. No problems were encountered with the batteries or battery charging during T020 operations. This system was M509 hardware that was used by T020.

e. Propellant supply subsystem. The PSS, including PSS tanks, stowage rack and resupply station, performed satisfactorily with the exception of minor difficulites experienced by the SL-4 crew, during attachment and detachment of the quick disconnect. This difficulty was attributed to temporary binding within the disconnect, caused by manual misalignment and the associated close tolerances. The SL-2 and SL-3 crews did not report any problems of this nature. This system was M509 hardware that was used by T020.

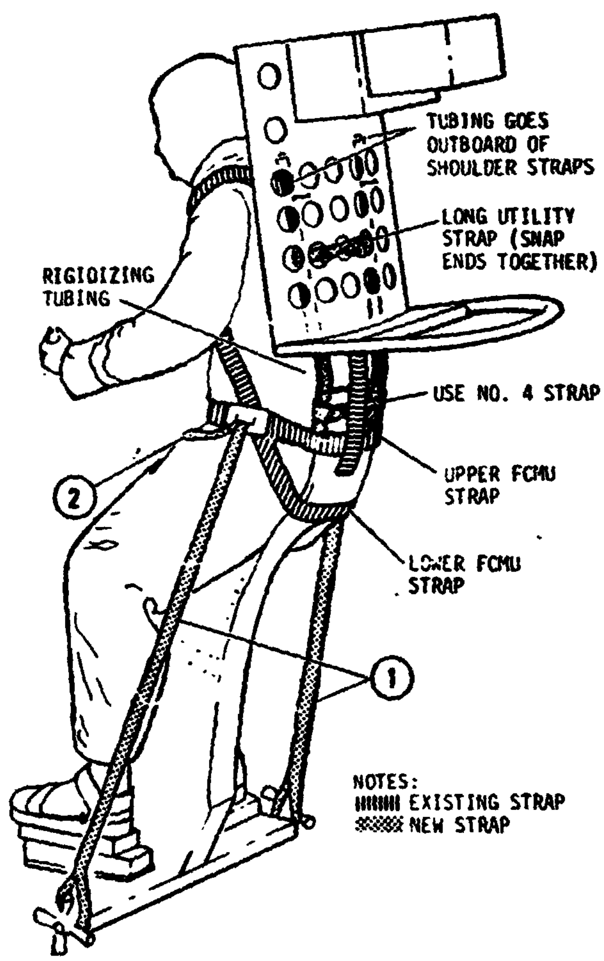

FIGURE IV-20. T020 RIGID RESTRAINT SYSTEM

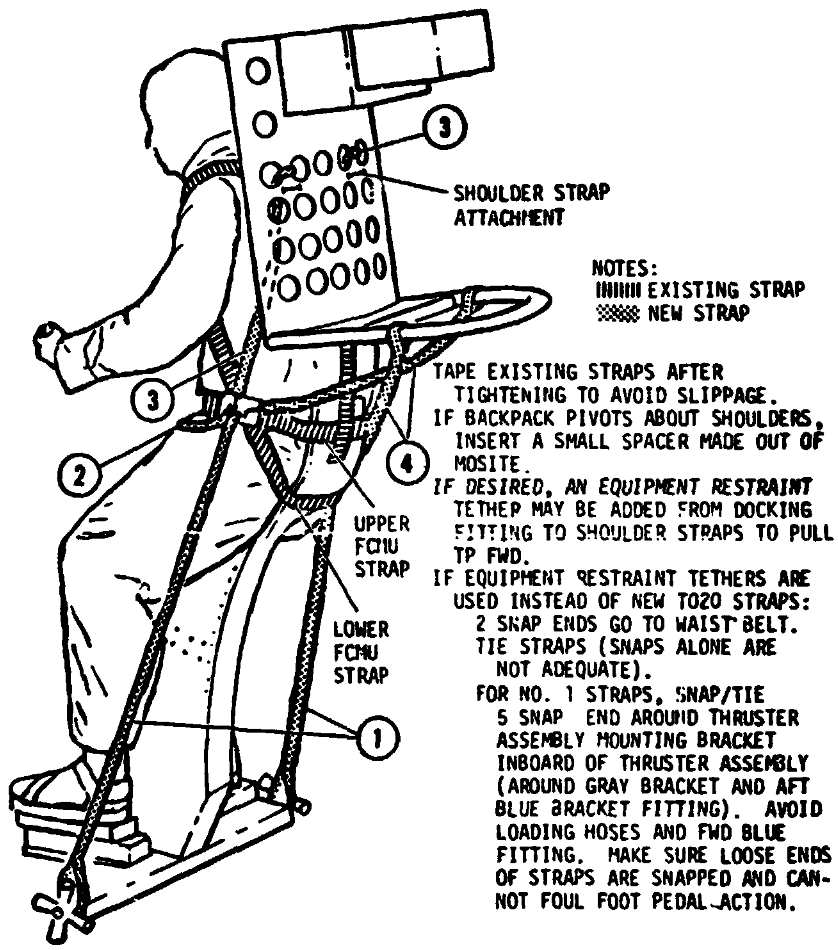

FIGURE IV-21. T020 NON-RIGID RESTRAINT SYSTEM - REAR VIEW

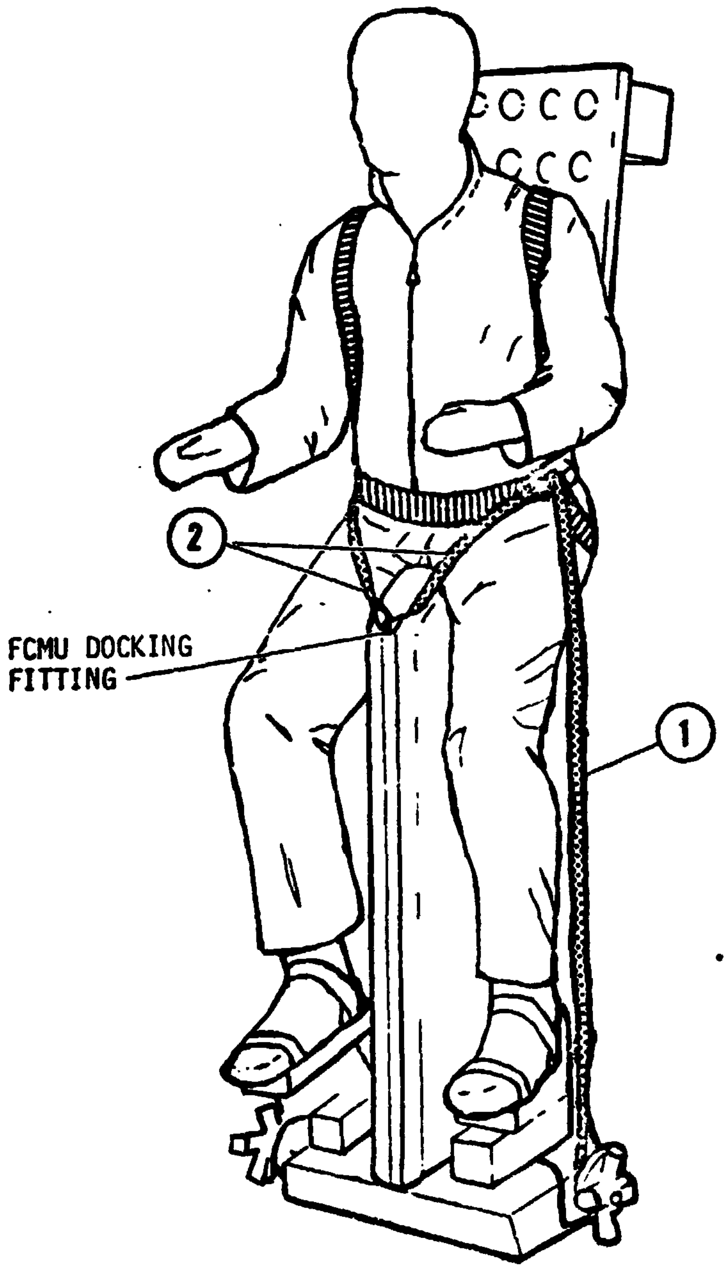

FIGURE IV-22. T020 NON-RIGID RESTRAINT SYSTEM - FRONT VIEW

f. Data Acquisition Camera. A malfunction of the Data Acquisition Camera (DAC) was experienced during the preflight checkout of T020 on DOY 241. The problem was corrected by replacing the DAC fuse, which had blown. No additional problems were encountered with the DAC during T020 operations.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. Crew voice comments made by the subject and observer during each test run and the following debriefings were recorded on the AM recorder and subsequently dumped to the ground. A complete set of SL-3 and SL-4 Mission Voice Dump Transcripts has been provided to the PI.

The 16mm color films taken during each test run were returned, processed and copies have been delivered to the PI. Two DACs were run simultaneously during the maneuvering sequences. One was mounted within the FCMU and used a split-image mirror system to obtain FCMU location data. The second DAC, mounted in the OWS dome, provided an overview of T020 maneuvers. Approximately 965 feet of film (590 feet on SL-3 and 375 feet on SL-4) were used to record the maneuvers.

Ten 35mm still photographs were taken on SL-3 to show the general experiment set-up. Comparable photographs taken on SL-4 were unsuccessful due to film loading problems.

Onboard TV coverage of selected operations was provided by using the video tape recorder. This coverage was subsequently dumped to ground for quick look evaluation by the PI. Copies of these recordings have been delivered to the PI.

7. Anomalies. No serious anomalies, that would require termination of the experiment run, occurred during the performance of the T020 experiment. However, several minor anomalies did occur and these are individually discussed in the following paragraphs.

a. Harness. The SL-3 test subject reported difficulties with restraint harness loosening and inadequacy during the first maneuvering sequence on DOY 231. These difficulties were not severe enough to cause early termination of the test, and the prescribed maneuvers were satisfactorily completed. However, the results were significantly influenced by the problem.

During the post-test comments, the CDR requested a method for improving the restraint harness effectiveness and possibly a method of rigidizing the backpack to the FCMU. A successful harness modification was evolved by the PI and the Crew Systems and Procedures personnel, using the LaRC simulators, MSFC high fidelity mockup and the JSC trainer hardware. The modification instructions, making use of

onboard straps and mosite rubber, were uplinked to the crew and successfully executed.

An additional shirtsleeve maneuver test, not previously scheduled, was performed on DOY 241 to evaluate the modified restraint harness system. The modified system proved adequate during this test and performed well during the pressure-suited maneuver sequence accomplished on DOY 256.

A harness modification kit which corrected these difficulties (see paragraph 4c), was developed and launched on SL-4. No problems were encountered with the modified harness system during the SL-4 runs on DOYs 15 and 24.

It should be noted that body restraint strap and harness difficulties were experienced in several other areas, indicating that future programs should give special attention to this general problem.

b. Batteries. The T020 and M509 hardware was exposed to excessive temperatures during the SL-1/SL-2 prehabitation phase. The two M509 rechargeable batteries had a surface temperature limitation of 90°F maximum. An investigation and overtemperature test (128°F for 10 days) was initiated at the Hardware Developer's to determine the possibilities of internal shorts, inability to recharge, contamination of the OWS ambient atmosphere and safety concerns. A hold, prohibiting M509 battery use, was issued to the crew on DOY 168 pending completion of the investigation.

Special test equipment and procedures for determining the batteries' conditions, by measuring individual cell voltage, were developed and launched on SL-3. Onboard battery tests performed on DOYs 216, 217, 219, 253, and 254 found no battery degradation and the batteries were approved for use. The batteries operated successfully and as predicted throughout the five T020 and eleven M509 test runs.

c. Data Acquisition Camera Fuse. The crew experienced difficulty with the FCMU-mounted DAC during checkout procedures on DOY 241. They commented that they were slow getting the run started because of DAC difficulties. They had found the DAC fuse blown and had replaced it. The camera performed well throughout the T020-1A run.

A sneak circuit analysis, performed at MSFC on the T020/DAC circuit, found no conditions to warrant additional precautions. Continued use of the system was recommended. Fuse failure was apparently caused by a temporary film hang-up.

The DAC was again successfully used for the T020 pressure-suited run on DOY 256. No additional difficulties were encountered during the T020 operations performed on SL-4.

d. Secondary oxygen pack. The secondary oxygen pack, SOP, required to accomplish T020 Functional Objective FO-3 was not launched, though approved, on either SL-3 or SL-4, due to higher-priority requirements to launch the "six-pack" rate gyro package on SL-3 and Comet Kohoutek observation equipment on SL-4.

A Flight Management Team decision permitted T020 to partially use an onboard SOP following the SL-3 DOY 236 EVA. SOP 12 was used from 6000 psi to 2000 psi, which provided approximately 11 minutes of operation, compared to approximately 19 minutes for full usage.

This item is not considered a hardware anomaly, but rather a successful workaround which permitted near-nominal hardware operations on SL-3.

e. Life support umbilical. The life support umbilical (LSU), used on SL-3 to accomplish T020 FO-2, was a lightweight version of the standard LSU. The onboard LSU was modified by the crew, per uplinked procedures, to obtain a lightweight version with greatly reduced dynamic effects. The LSU cover, instrumentation lines, communication lines, etc., were removed, leaving only the oxygen supply line.

The modification effect on T020-2 run obtained better maneuvering characteristics due to the reduced umbilical dynamic effects. However, recording the test subject's comments and communication with the observer during the suited run was not possible, due to communication line removal. This limitation was acceptable to the PI, since the subjects comments are considered supplementary to the prime data, film, observer comments and subject debriefing. However, several procedural problems were encountered due to the communication lack between the subject and the observer.

f. Procedural. Several procedural errors occurred during the various T020 runs. These deviations from planned procedures resulted in the partial loss of both audio and photographic data. Adequate data was obtained to evaluate the experiment performance.

H. Experiment T027 - Contamination Measurement (Sample Array)

The Principal Investigator for Experiment T027 is Dr. J. Muscari, Martin Marietta Aerospace, Denver, Colorado. The experiment hardware was developed by Martin Marietta Aerospace.

1. Experiment Description. Window contamination on previous Gemini and Apollo flights interfered with star sightings and lunar surface photography experiments. Major sources of contaminant deposition were thruster firings and molecular evaporation from the window seals.

a. Objectives. The primary objective of the Sample Array portion of the T027 experiment was to obtain controlled data on the degradation effects of Skylab contaminants on the optical properties of various windows, mirrors and diffraction gratings. A secondary objective was to obtain near-real-time data on accumulative contamination rates during sample exposure.

b. Concept. Carefully selected optical samples were to be measured pre-flight and then were to be exposed to the external space environment for controlled time periods. The samples were to be deployed through the solar scientific airlock (SAL) on a sample array system for five days. Two quartz-crystal microbalances (QCMs) were included on the sample array system to measure accumulative deposition rates; one oriented toward the sun, the other normal to sun line.

The T027 sample array data was to be used with data from Experiment T027/S073 Photometer (refer to Subsection I), for overall contamination evaluation by the PI.

c. Hardware Description. The sample array system (figures IV-23 through IV-26) was designed to expose optical samples to the space environment for controlled periods. The sample array (SA) was deployed outside the spacecraft on a rod; 248 samples of 16 different types were exposed. The samples included window materials, mirrors, gratings, and other optical surfaces designed for various wavelength regions. The assembly consisted of: an upper face plate, an upper box assembly immediately behind the face plate, a waist post, and lower face plate (see figure IV-23). Motordriven, automatically-sequenced carrousels were located beneath the upper and lower face plates. Holes were provided in the face plates to allow sequential exposure of the carrousel-mounted optical samples for predetermined time periods. A valve, or cover plate, was provided over the holes in the forward face plate to seal the upper carrousel when in the retracted position. The upper (daily) carrousel (located beneath the upper face plate) contained 30 samples. Carrousel motor sequencing and the face plate hole pattern were designed to allow exposure to the space environment of 25 samples, five at a time, for 24 hours. The remaining five samples, which were control samples, were to be exposed to space for the short period from last carrousel indexing to SA retraction, if the SA were exposed for the planned 120 hours. The first upper carrousel movement was designed to occur 24 hours after the

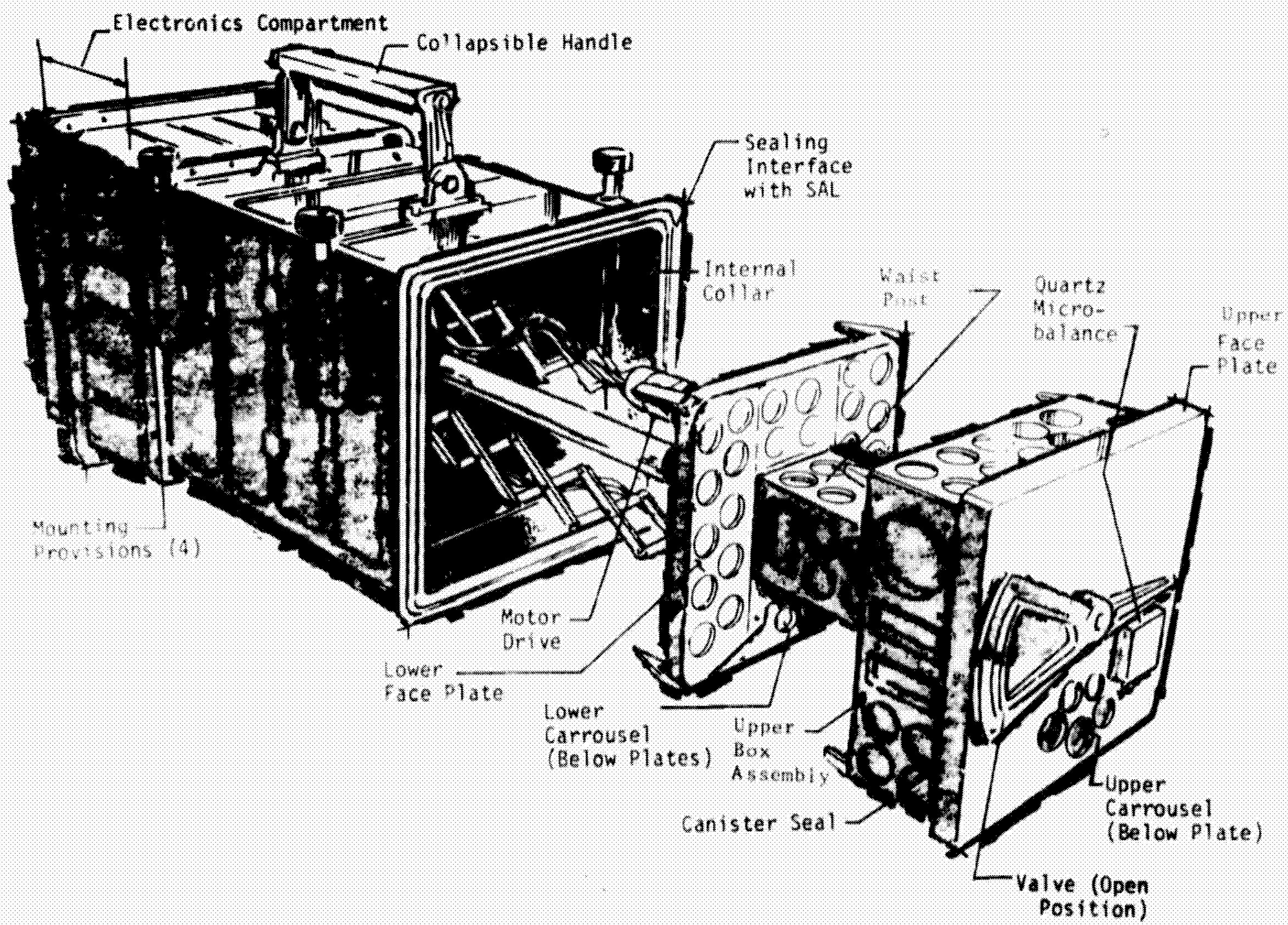

FIGURE IV-23. SAMPLE ARRAY EXTENDED

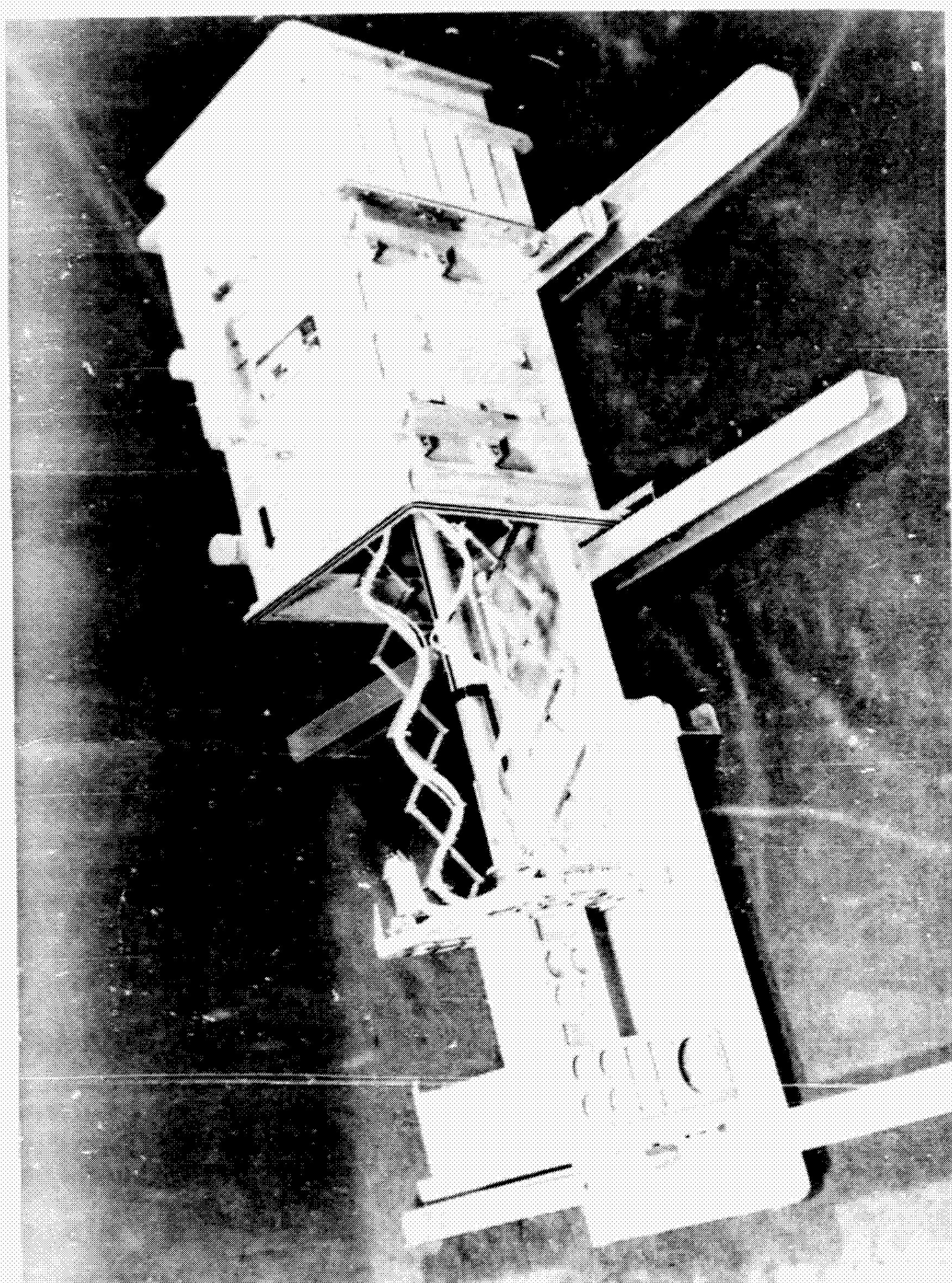

FIGURE IV-24. SAMPLE ARRAY IN EXTENDED POSITION

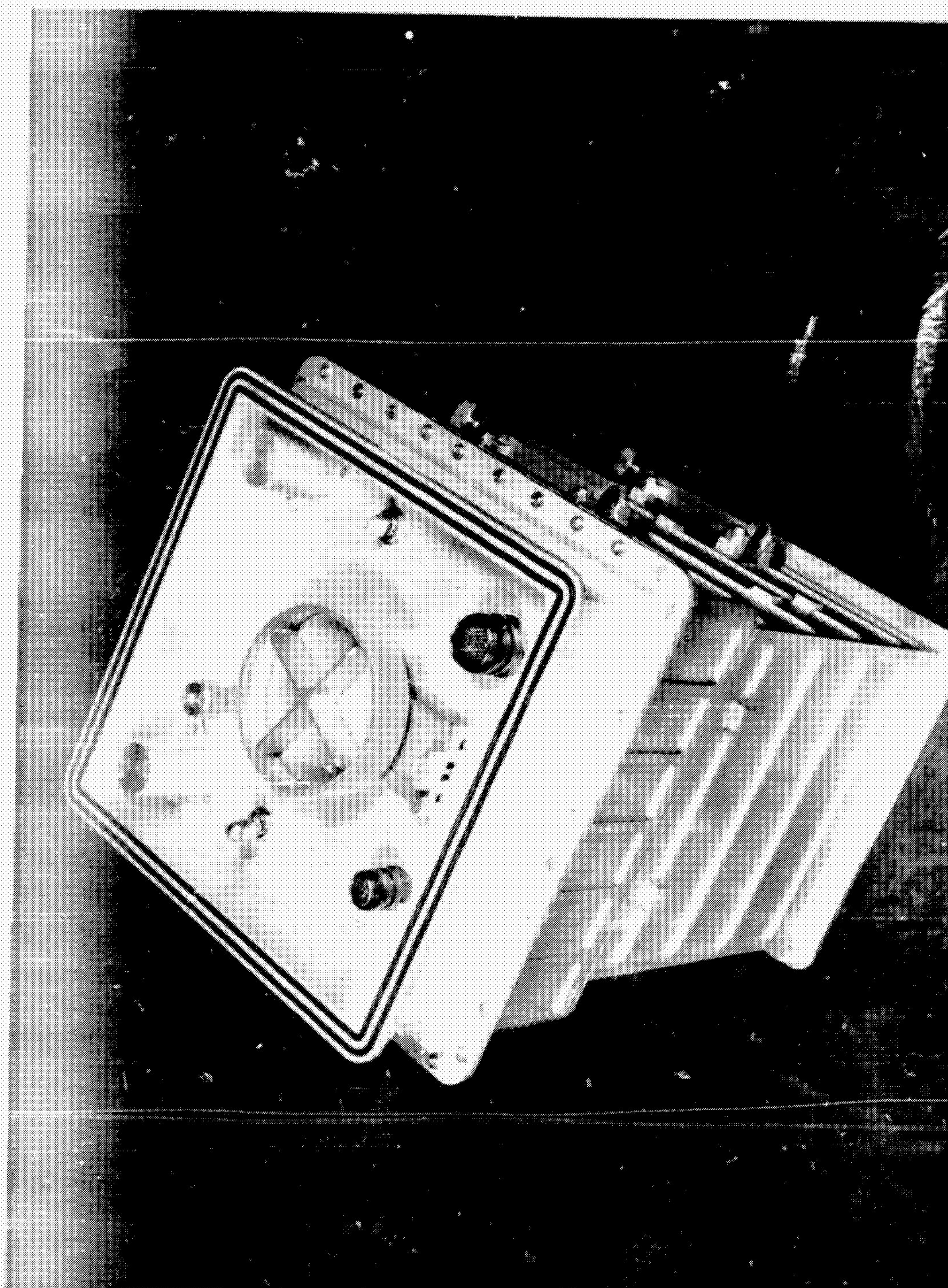

FIGURE IV-25. SAMPLE ARRAY EXPERIMENT (REAR VIEW)

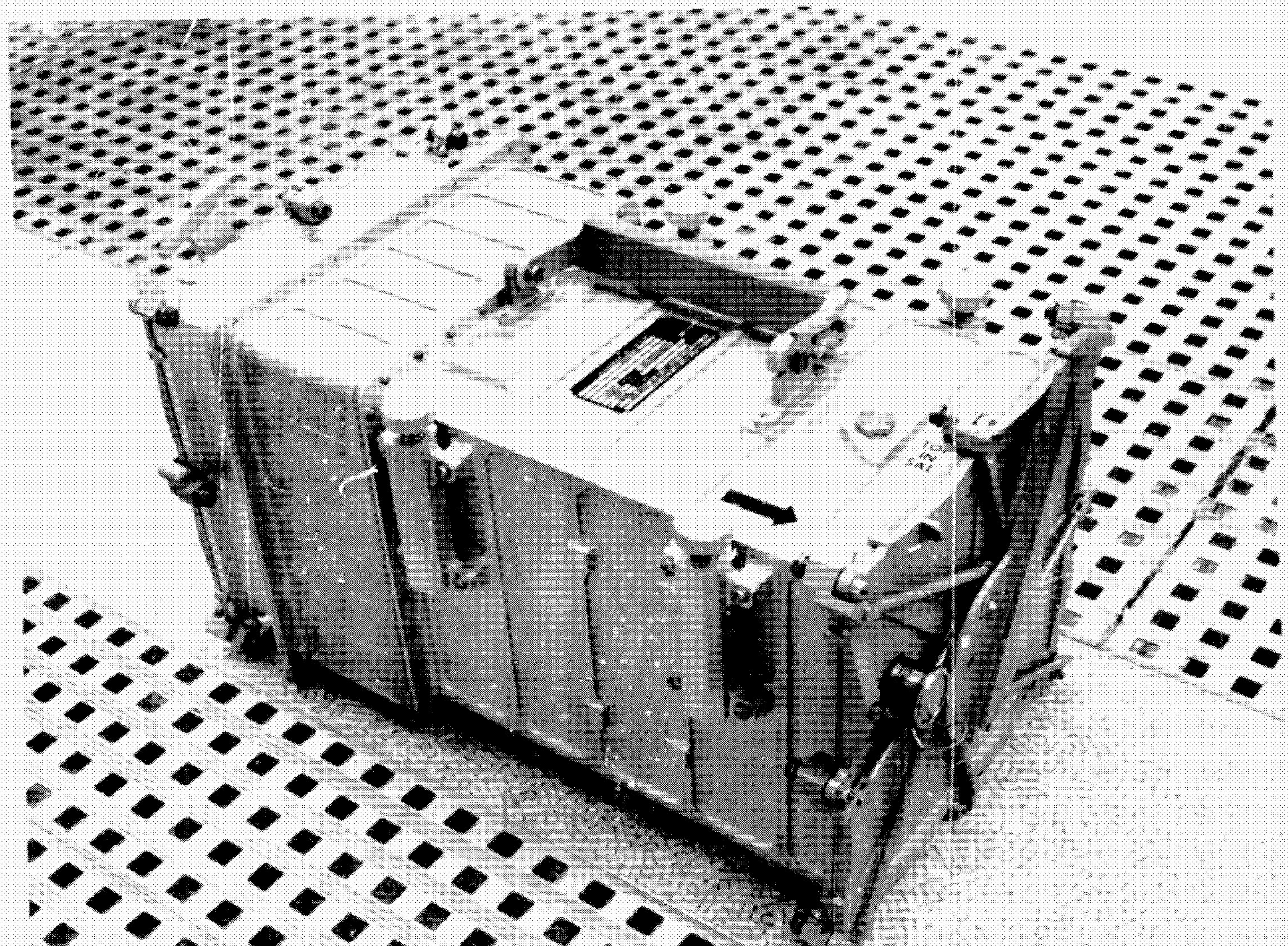

FIGURE IV-26. SAMPLE ARRAY STOWAGE CONFIGURATION

automatic sequence was started. The lower (hourly) carrousel (located beneath the lower face plate) contained 78 samples arranged in three concentric rings. The lower carrousel was designed to expose samples successively for one-hour durations (inner two rings) and for two-hour durations (outer ring) during the first 25-hour period of experiment operation. The four samples exposed after 25 hours of operation were to remain exposed during the balance of the exposure time. The first of 26 carrousel movements was designed to occur when the automatic sequence was initiated.

After the exposure period, the SA was retracted and sealed in space vacuum and returned to earth for analysis and study.

2. Experiment Operation. The SA was launched on SL-1. Non-availability of the solar SAL (which was used to deploy the parasol sun shield), made it necessary to move the T027 Sample Array experiment operations to the anti-solar SAL. It was recognized that on the anti-solar side the experiment hardware would be exposed to much colder operating temperatures than on the solar side. For example, thermal analysis indicated that the upper carrousel face plate would reach a temperature of +55°C at β = 50 degrees when deployed from the solar SAL, whereas operation from the anti-solar SAL would reduce the temperature of the face plate to approximately -62°C. It was noted that the upper carrousel face plate would be the hottest or coldest area, depending upon which SAL the experiment was using. It was also recognized that qualification testing had been performed at a minimum temperature of -18 ± 3°C, which was 44°C above the probable operating point. However, inspection of the experiment design and past performance records indicated that operation from the anti-solar SAL would be satisfactory even though the temperature levels would be considerably colder than desired. The judgement at the time was that the worst that could happen would be that one or both of the carrousels or carrousel mechanisms would cold-seize and that the carrousels would therefore fail to operate. The PI stated that this condition would be a degradation, but an acceptable one, and that he could still achieve 80% of the original objectives if both carrousels should fail to index. Even with both carrousels seized 149 samples of the 248 would still be exposed. He was strongly in favor of performing the experiment during the SL-1/SL-2 mission.

Anti-solar SAL operation resulted in no telemetry capability for the experiment because the anti-solar SAL instrumentation outlet was not wired for any of the six sample array measurements.

This factor was discussed with the PI. The decision was to operate the experiment during the SL-1/SL-2 mission, rather than wait until later missions when special adaptive telemetry cabling might have been provided to allow transferring the signals to existing T027/S073 photometer telemetry channels. The PI felt that operation on later missions would greatly reduce the chances of collecting significant outgassed deposition elements on the samples. He preferred to get good sample deposition data even at the sacrifice of QCM and the carrousel drive data.

With only limited cluster power available during the early part of the mission, and only one SAL available for experiment deployment, it was necessary to reschedule this experiment activity to a later operating time and to reduce the planned exposure time as follows:

	Mission Operation Schedule	
Event	Planned Pre-Mission	Actual
Deployment	DOY 148	DOY 168
Retraction	DOY 152	DOY 170
Exposure Time	120 Hours	46½ Hours

The later deployment and shorter exposure times undoubtedly resulted in operation during a lower outgassing rate period and produced lower deposition levels.

Table IV-14 reflects the operating times and associated operations for the experiment. All operations were reported to be normal except for one anomaly. When the experiment had been removed from the SAL and before end plate installation, the crewman noticed that the upper carrousel valve had not fully seated and that the cool surfaces were rapidly collecting moisture and forming ice due to cabin atmosphere humidity. He performed a complete closure when the unit warmed up. The PI indicated that he did not want the valve reopened when the end plate area was being evacuated to re-evacuate the inner sample compartment areas. The reasoning was that if the valve was open, a leak path would be exposed that would allow cabin air and humidity to flow into the evacuated inner sample compartment areas and possibly further contaminate the samples.

One other incident involving the use of T027 SA equipment occurred. On DOY 172 after the SA had been transferred to the SL-2 CM for return, the empty SA stowage box was used to store three urine separators. Apparently there was a desire to store the separators rather than dump them through the trash airlock into the trash stowage tank. It was necessary to evacuate the stowage container to minimize bacterial growth within the separators and propagation of the uratic residuals into the cabin space. During the stowage container evacuation operations, it was found that the crew could not pull a vacuum on the container. Apparently, the crew did not have all four stowage container cover latches engaged; only the two away from the hinge side of the cover. With all four cover latches engaged, a vacuum was successfully pulled on the stowage container interior. The crew had not reported any problem with the evacuation of the stowage container during experiment stowage.

TABLE IV-14. T027A SAMPLE ARRAY OPERATION

DOY	Rev	Mission Day	GMT	Operations
168	491	24	1845 thru 1915	1. Pressurize stowage container and remove SA. 2. Pressurize end plates and remove end plates. 3. Install SA in SAL and open SAL door. 4. Open outer carrousel valve and remove operating knob. 5. Attach extension rod and extend SA. 6. Connect power cable, turn power ON.
170	519	26	1545 thru 1815	1. Turn power OFF, disconnect power cable. 2. Retract SA and remove extension rod. 3. Attach carrousel operating knob and close carrousel valve. 4. Close SAL door. 5. Remove SA from SAL. *6. Final closure of carrousel valve. 7. Attach end plates. Evacuate end plates. 8. Stow in stowage container and close stowage container. 9. Evacuate stowage container.
172		28	1600	1. Repressurize the stowage container and open. 2. Remove the SA and transfer to CM locker A-8.

NOTE: *This was an abnormal procedure.

3. Experiment Constraints. The experiment constraints were successfully met during the mission except one. This was an important operational requirement stating that the SA system was to be scheduled as early as possible in SL-2, when the Skylab outgassing was greatest.

This constraint was violated due to scheduling of higher priority experiments. Accordingly, the combination of late deployment, short exposure, and anti-solar SAL use reduced data effectiveness by approximately 50 percent.

4. Hardware Performance. During the SL-1/2 mission, the SA was installed in the anti-solar SAL, extended and retracted, and samples were exposed to the space environment. It was not possible to confirm the rotation of the carrousels during the mission or to gather QCM data, due to the lack of telemetry capability from the anti-solar SAL. The experiment appeared to perform as planned, with the exception that the upper carrousel valve did not fully seat while exposed to space vacuum, and was closed only after removal from the anti-solar SAL, inside the OWS.

The sealed SA, in its ground storage container, was returned to Martin Marietta Aerospace, Denver Division, on June 26, 1973. The SA was transferred to the Failure Analysis Laboratory for a pressure and residual gas analysis of its various chambers. During this test, it was found that the front face plate and valve plate were not fully seated to insure proper sealing of the upper carrousel chamber. Quantitative results of this analysis are presented in table IV-15.

TABLE IV-15 RESIDUAL GAS ANALYSIS, T027 SAMPLE ARRAY SYSTEM

Sampling Area	Pressure	Major Constituent
Ground stowage container	Above 600 torr	High nitorgen low in water & oxygen
Electronic control panel cover plate	Above 40 torr	Oxygen 20% of nitrogen peak
Sample cover plate	About 270 torr	High nitrogen & water low oxygen, sample area at OWS pressure
Upper carrousel/all samples	Estimate 270 torr	High nitrogen & water low oxygen, no outstanding contaminants

Following the pressure and gas analysis, the SA was moved to the Research and Development Laboratory. Here the SA was disassembled under the supervision of the PI. Each of the samples was removed, catalogued, photographed and examined for contamination.

During the disassembly of the SA, the valve actuator mechanism was removed and visually examined for any mechanical binding that might have prevented the valve and face plate from fully closing and sealing. There was no evidence of any mechanical binding. It was observed, however, that the threads on the end of the rod section of the valve actuator mechanism were heavily coated with a grease identified as Brayco 813. One of its characteristics is solidification at a temperature of -18°C. The temperature of the threaded rod section had been considerably below -18°C since the SA had been exposed to space vacuum on the anti-solar side for 46½ hours. It was speculated that the hardened grease prevented the valve actuator knob from being fully tightened while the unit was cold and hence the valve and the face plate were not sealed. In reference to this conclusion, it should be re-emphasized that the SA was not intended to be used at the anti-solar SAL. It was designed to operate at an environment of 70°F or higher. The use of this grease was acceptable for these conditions, and in fact was called out on the applicable engineering drawings.

The post-mission contamination investigation results indicated that the daily carrousel did not index from its prelaunch conditions. Since SA telemetry was not available, it could not be verified that a command signal was sent to the drive motor. The exact SA temperature history was not available for the same reason. The cold operating temperature at the anti-solar SAL (estimated to be -80°F) may have caused a mechanism binding a few hours after deployment. The hourly carrousel had either not indexed or had completely indexed (i.e., the initial and final positions were the same). Contamination analysis of the carrousel samples was inconclusive as to whether they were exposed or not.

Discounting thermally induced mechanism seizure, there were four other possible reasons for the carrousels not indexing:

a. The circuit breaker supplying 28 VDC power to the anti-solar SAL power outlet was not closed by the crew as required by the checklist,

b. The SA power switch was not placed in the ON position prior to initiating the automatic sequence as required by the checklist,

c. The automatic sequence was not initiated after power was supplied as required by the checklist, or

d. The SA internal power supply or carrousel motor drive logic circuit failed to respond in a normal manner.

As a result a functional operation test of the SA was made under ambient conditions. The SA was reassembled without samples and a two-part test was run. The first part was a 48-hour test with a telemetry cable attached. This allowed for a complete 26-turn cycling of the lower carrousel (once at initiation and once each hour for the first 25 hours) and two indexes of the upper carrousel (at the 24th hour and the 48th hour). The second part was a rerun of the first, with no telemetry cable attached, and was limited to 24 hours. The SA worked successfully for both tests, showing no evidence of malfunction.*

The SA was tested in a thermal-vacuum chamber under conditions simulating exposure from the anti-solar SAL. The hourly carrousel functioned properly; however, the daily carrousel seized at the twenty-fourth hour of operation after partially indexing (approximately 30%) into position.*

Post-test inspection of the upper carrousel drive mechanisms showed that there was no obvious sign of mechanism jamming or interference. It is speculated that high friction within the motor gear train and carrousel mechanism bearing surfaces at the abnormally cold operating temperatures on the upper carrousel drive motor caused the drive motor to stall after partially indexing the mechanism. It was noted that the upper carrousel Geneva drive mechanism had a 1/3 smaller mechanical advantage than the lower carrousel drive mechanism. Therefore, the upper carrousel was the one more likely to stall under equal loading conditions. The partially indexed position of the upper carrousel, found in the test, was not the returned-from-orbit position of the upper carrousel.

The test results did not conclusively eliminate the possibility of an actuation error which did not start the automatic carrousel drive cycle. However, during the crew debriefing, the crewman verified that the checklist had been followed; that the power switch had been turned on and the start switch actuated. Assuming that the SA had been actuated properly on orbit, it is possible that the upper carrousel could have stalled without any noticeable carrousel movement.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission except that the operation at the anti-solar SAL resulted in the loss of telemetry capability to transmit QCM data, to verify carrousel operation, and to monitor temperature. The abnormally low operating temperature had little effect on the scientific data, even though a problem occurred with the outer carrousel valve and the carrousels may not have rotated.

6. Return Data. The data consisted of the SA sealed in its ground storage container which was returned to the PI in June, 1973.

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* Refer to Reference Section for Test Reports.

To substitute for the data lost in being unable to expose samples on the OWS solar side, the PI has obtained, and made contamination measurements on, portions of returned experiments D024 and S230, and has made arrangements to obtain portions of Experiment S149. These experiments were exposed on the OWS solar side and retrieved during EVA.

7. Anomalies. The experiment was operated from the anti-solar SAL rather than from the solar SAL as planned. The experiment was originally to be initiated on DOY 148 and operate for 120 hours, but was actually initiated on DOY 168 and operated for 46½ hours. The upper carrousel valve did not fully seat prior to retraction, and the carrousels apparently did not rotate. It is noteworthy that all of them could have been attributable to the unanticipated flight planning changes necessitated by the solar SAL unavailability, rather than to any deficiencies in the experiment itself.

I. Experiment T027-Contamination Measurement and

Experiment S073-Gegenschein/Zodiacal Light (T027/S073 Photometer System)

The Principal Investigator for Experiment T027, is Dr. J. Muscari, Martin Marietta Aerospace, Denver, Colorado.

The Principal Investigator for Experiment S073, is Dr. J. Weinberg, The State University of New York at Albany, Albany, New York.

The Hardware Developer was Martin Marietta Aerospace, Denver, Colorado.

1. Experiment Description. The objective overlap led to a photometer system which would permit use of the same hardware by both experiments. Each time the system would be used, it would measure all light in its field-of-view (FOV). Scattered light from contaminant material around the OA must be separated from the total measurement to analyze the skyglow, which is primarily zodiacal light and starlight. Similarly, quantitative study of contamination would not be possible without knowing the skyglow characteristics. The fact that both S073 and T027 would require knowledge of contamination and zodiacal light led the PI's to collaborate and combine the observations into a joint observing program.

a. Objectives. The experiment T027 (Photometer System) objective was to measure the sky brightness background caused by solar illumination of the particulate contaminants found about the OA.

The experiment S073 objective was to measure the skyglow surface brightness and polarization over as much of the celestial sphere as possible at several visible spectrum wavelengths.

b. Concept. The photometer system was to measure three parameters which fully characterized the radiation from the skyglow and from the OA corona; i.e., total brightness, polarized component brightness, and the polarization plane orientation. Skyglow (zodiacal light, Gegenschein, starlight, F-region airglow) measurements were to be obtained on the dark side of the orbit. Measurements on the sunlit side and at the terminator were to characterize the contaminant cloud and to provide skyglow information.

Particular importance was placed on measuring the amount of polarization, which increases in proportion to the amount of light scattered off particulate matter surrounding the OA. The optimum time for OA corona discrimination with respect to the nightglow (primarily zodiacal light) would occur just before the OA left, or entered the earth's shadow.

The principal photometric data collecting method was to scan the areas under study (e.g., ecliptic plane, anti-solar direction, and other regions of the celestial sphere) with a photoelectric polarimeter. The polarimeter was to utilize Fabry optics for measuring, at selected wavelengths, the three parameters. The system included a rotating polarizer and a DC detection system with photomultiplier tube (PMT). The data obtained was subsequently to be used in a computer program to provide synchronous detection by digital techniques. Auxiliary data would include photographs of the observed areas, plus adequate timing and crew comments to correlate the recorded photometric data with the position information to be determined from the photographs.

c. Hardware Description

(1) Photometer canister and extension mechanism. This unit was the basic structural item of the photometer system. It provided a mechanism for extending and pointing the photometer head, Experiment S149 - Particle Collection, or the portable color television system camera through the SAL. The canister maintained the OWS cabin pressure integrity while the photometer system was extended through the SAL. The canister had double seals which mated with the SAL, and O-ring seals in the pressure bulkhead to seal the extension rods. An electronics compartment was provided at the canister end opposite the SAL mating surface. Bracketry was mounted on the canister top for stowing the extension rods, eject tube, tube plug, demountable handle, crank handle, dust covers and shorting plug.

The canister contained the extension mechanism which was manually extended by the extension rods (see figure IV-27). This mechanism could be deployed 18 feet beyond the OWS skinline when all seven extension rods were used. The 18-foot deployment placed the photometer head beyond the plane of ATM solar panels (when using the solar SAL) which would have enabled observations with the photometer head at a 90° trunnion position without FOV interference from the ATM canister. The entire system external to the SAL could be ejected using the eject tube if the extension mechanism could not be retracted.

Motors and encoders for positioning the head (see figure IV-28) in trunnion (elevation) and shaft (azimuth) were on the extension mechanism end. The trunnion mechanism controlled scanning of the head between the 0° and 112.5° position. The shaft mechanism controlled scanning between 0° and 354.4°. Mechanical stops prevent scanning beyond these limits. Encoders provided octal displays of position to the crew and AM data system. The trunnion axis was normal to the SAL deployment axis, and the shaft axis was coincident with the SAL deployment axis.

(2) Control panels. There were four control panels (see figures IV-29 through IV-32) on the canister: a mechanical panel on the face opposite the SAL mating surface; a common panel and compartment which was removable and mounted alongside the common panel; and an

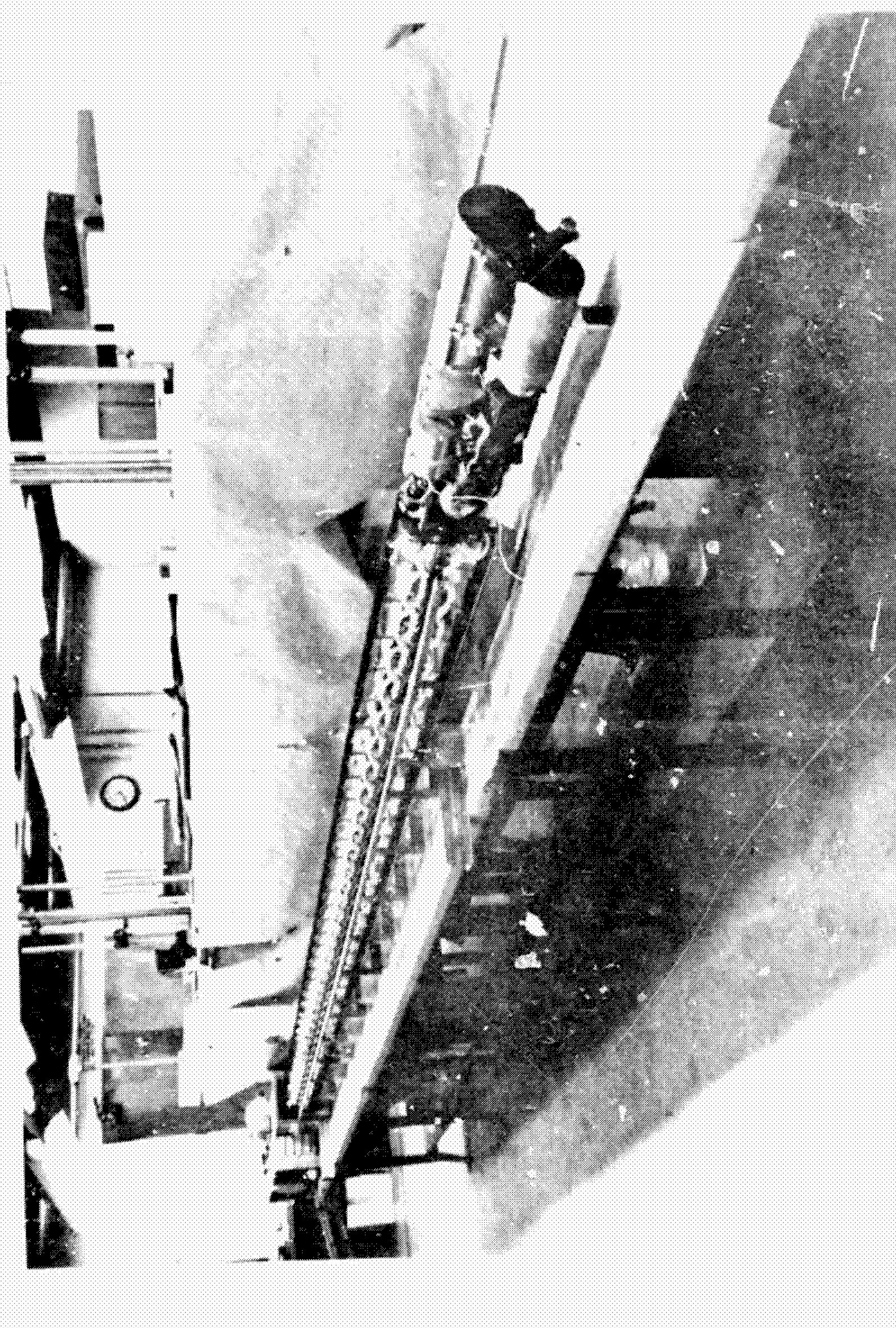

FIGURE IV-27. T027/S073 PHOTOMETER SYSTEM EXTENDED

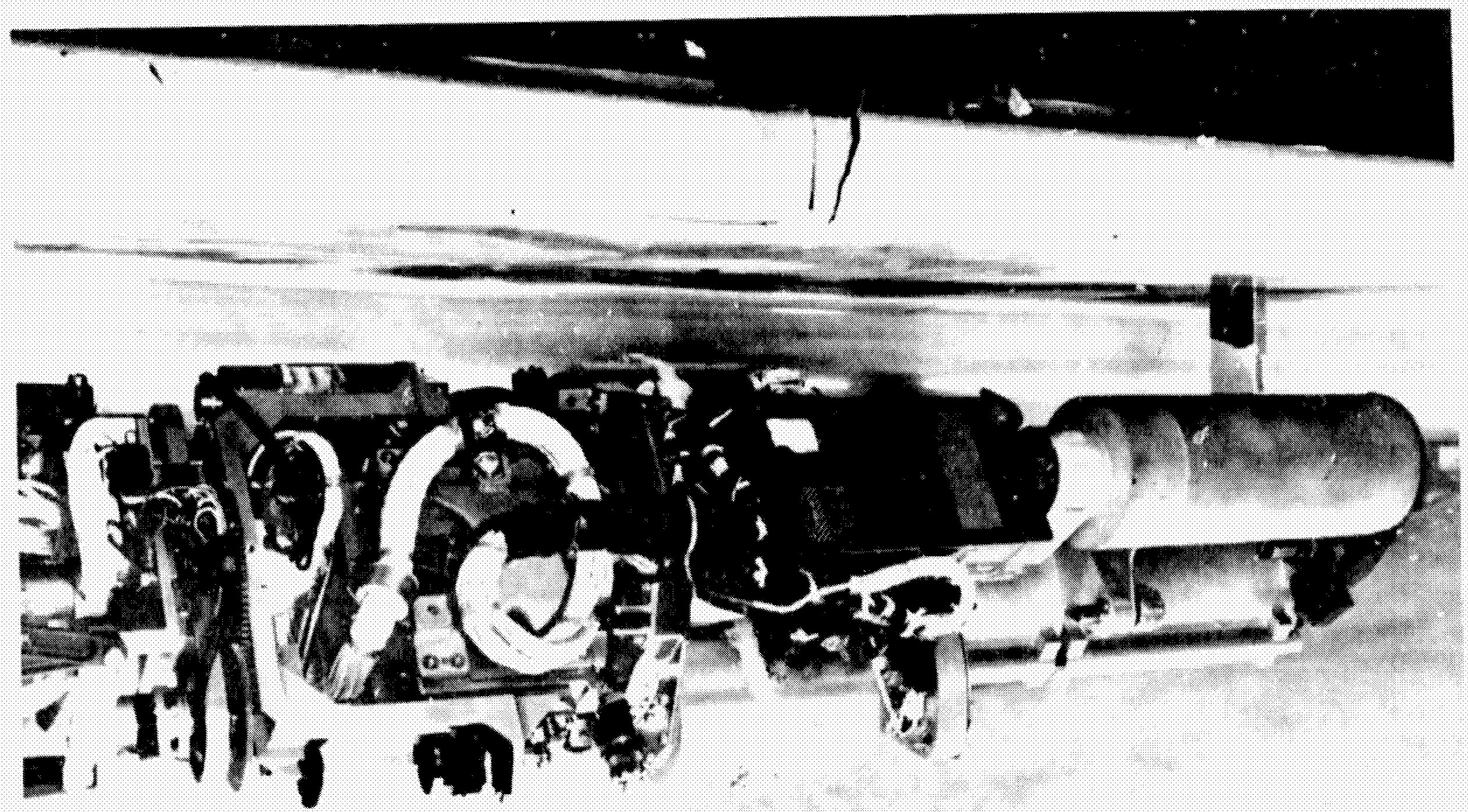

FIGURE IV-28. T027/S073 PHOTOMETER SYSTEM HEAD

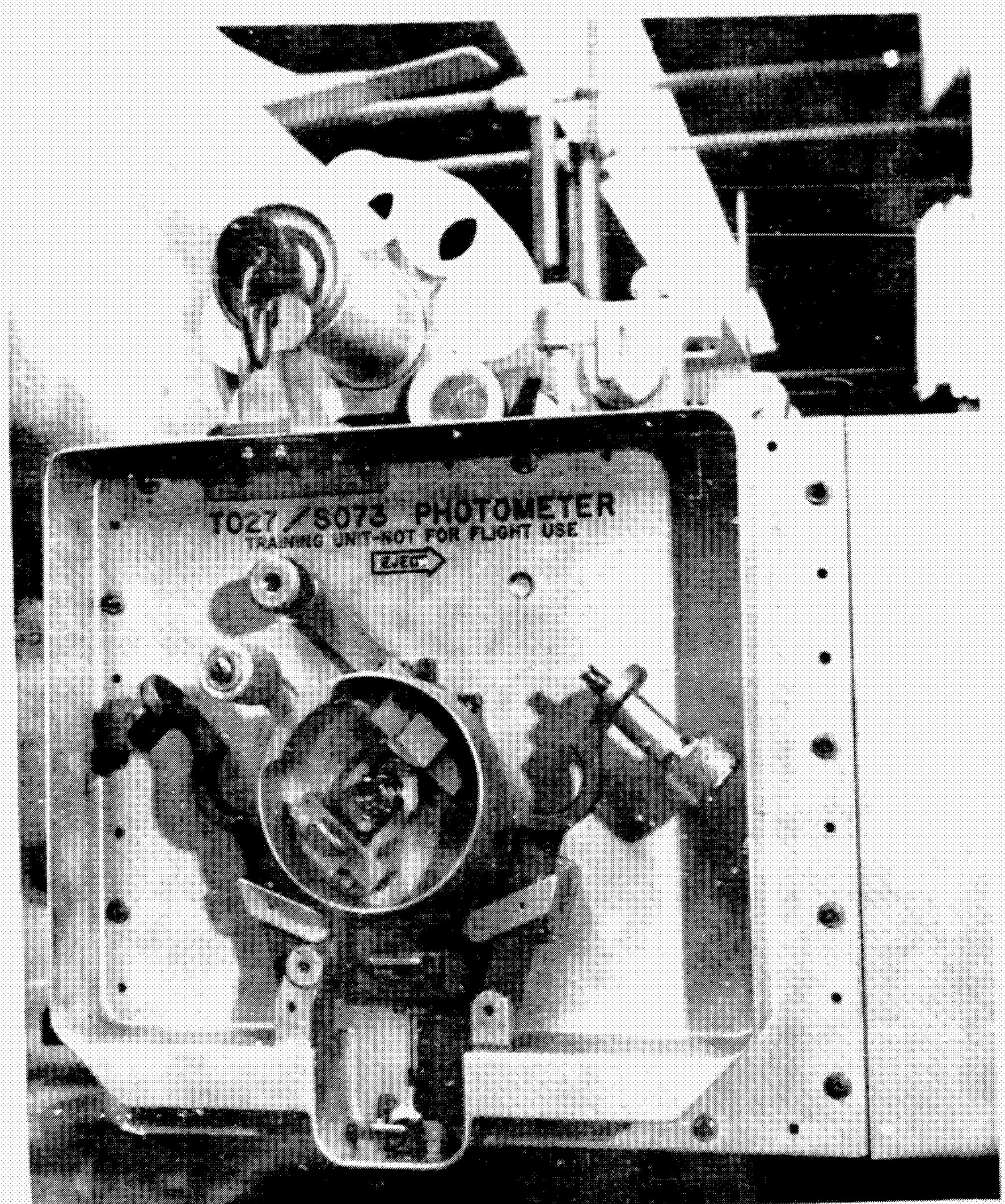

FIGURE IV-29. T027/S073 PHOTOMETER SYSTEM REAR PANEL

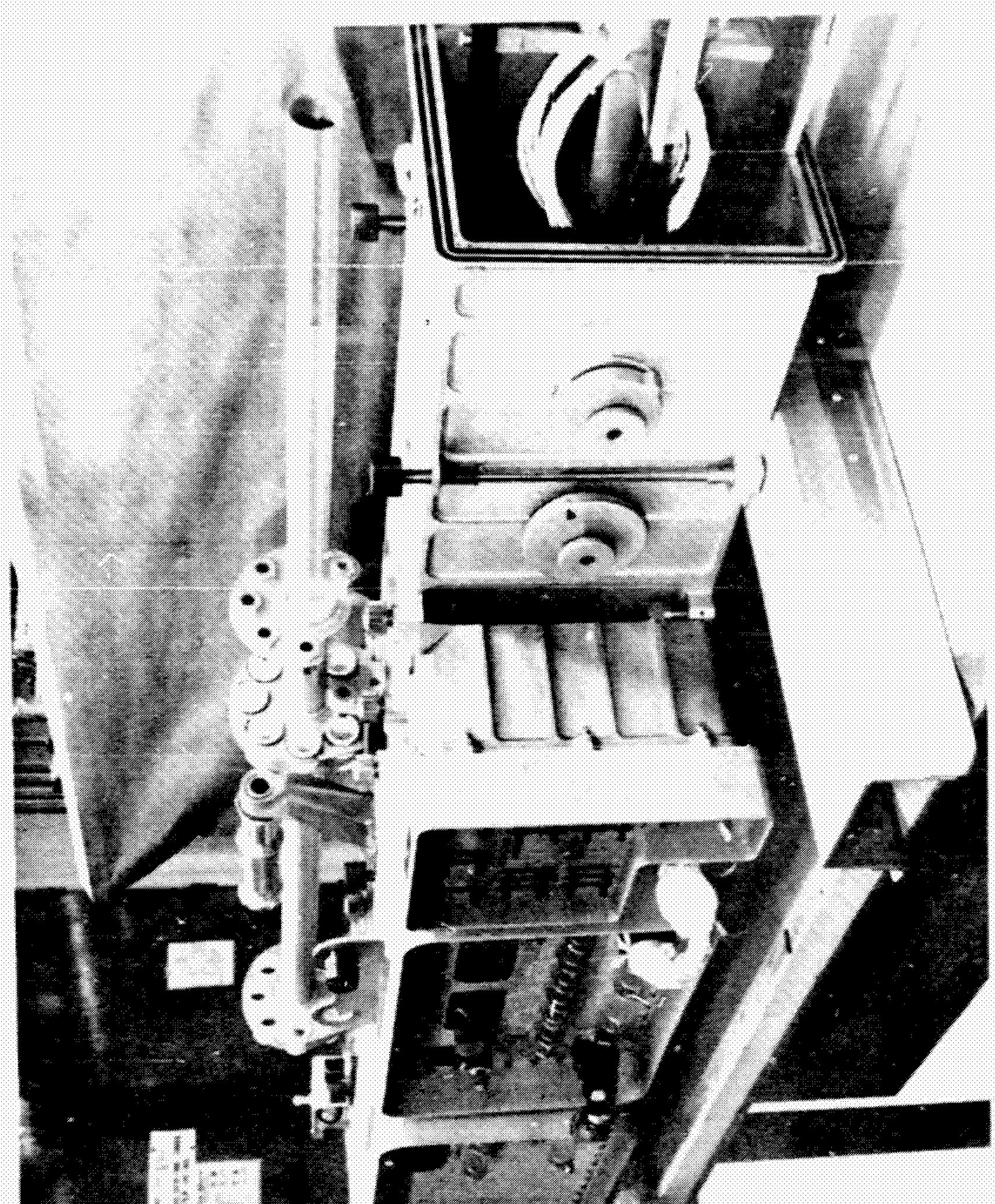

FIGURE IV-30. T027/S073 PHOTOMETER SYSTEM SIDE PANELS

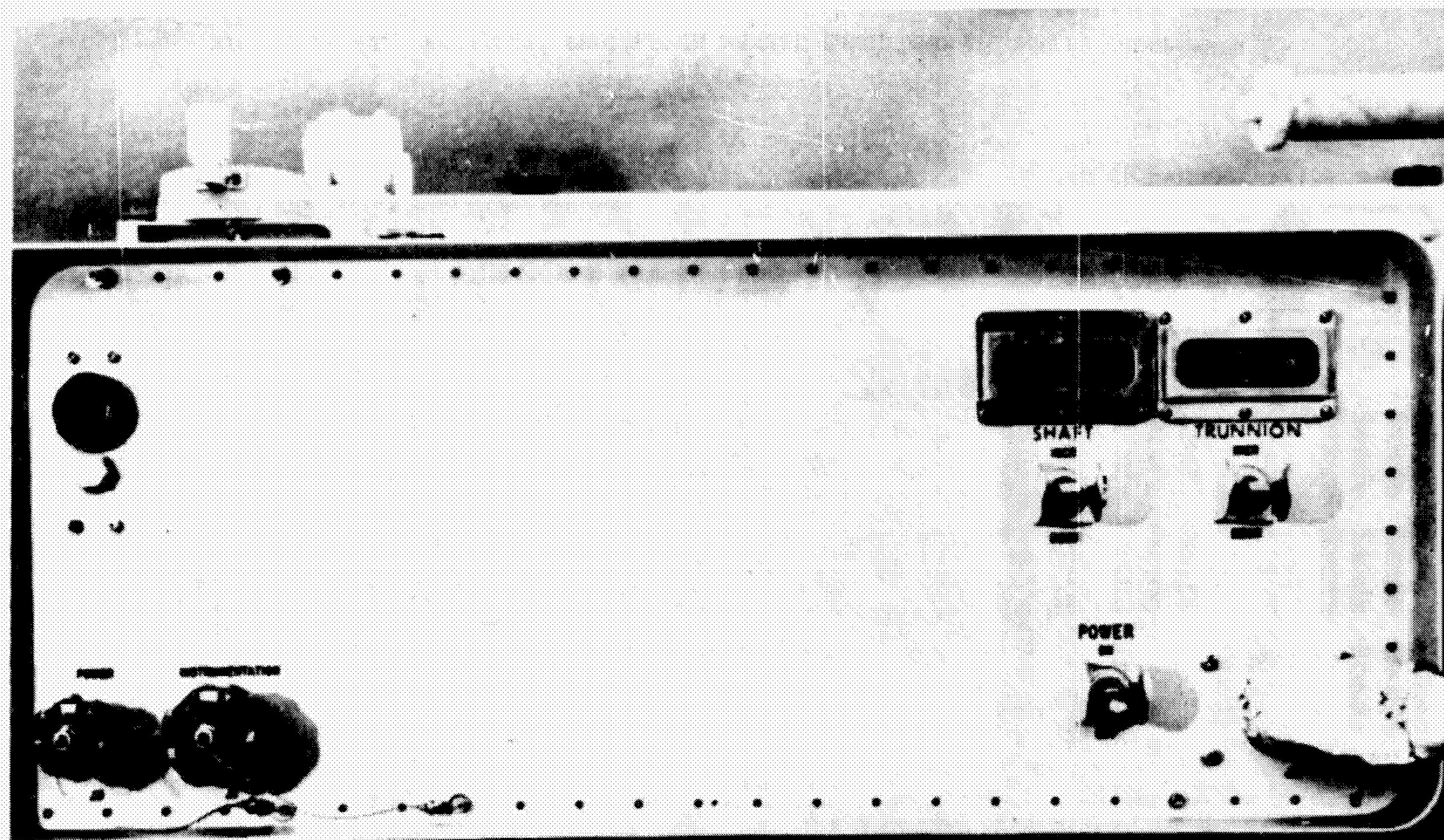

FIGURE IV-31. T027/S073 PHOTOMETER COMMON CONTROL PANEL LAYOUT

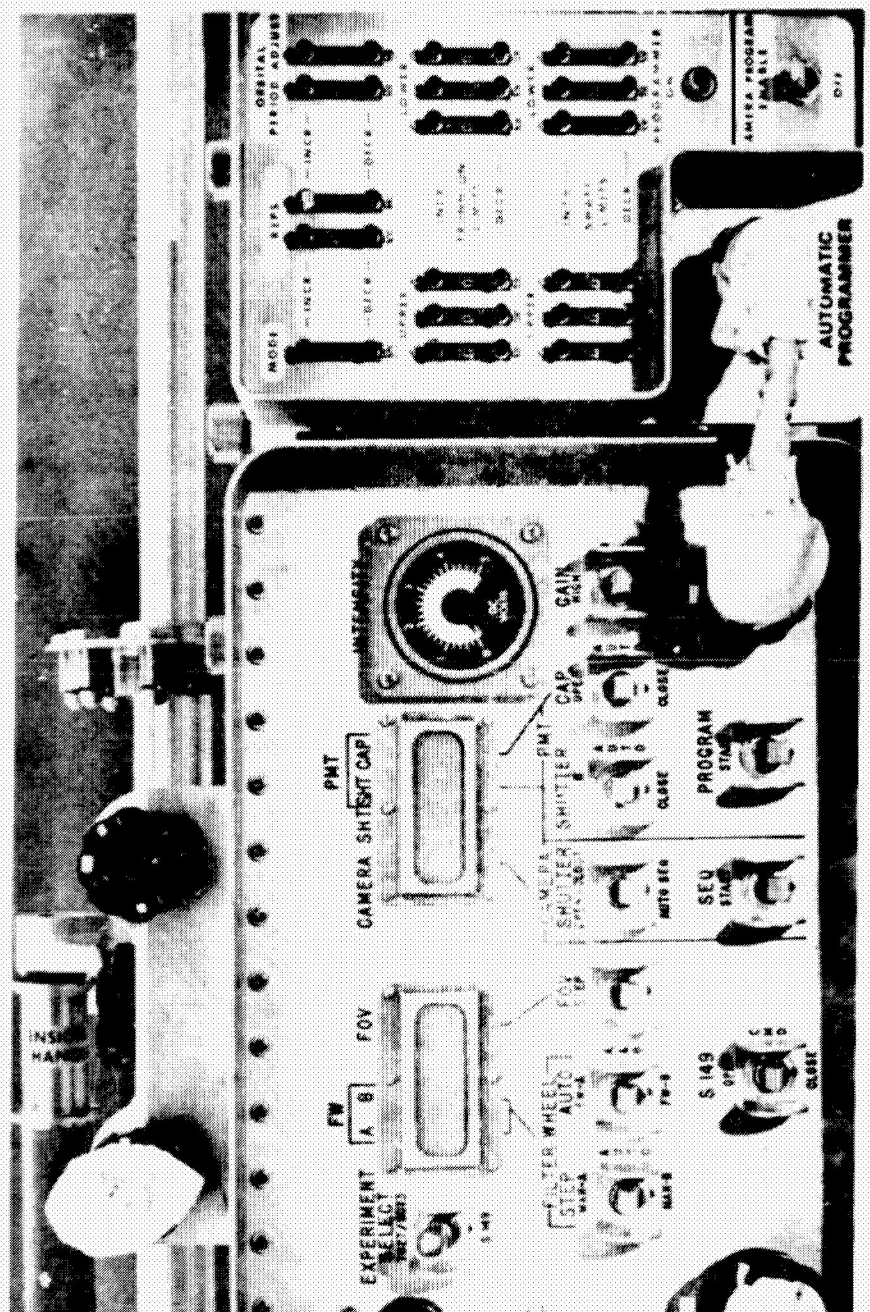

FIGURE IV-32. T027/S073 PHOTOMETER MANUAL PANEL AND AUTOMATIC PROGRAMMER

automatic programmer control panel and compartment which was removable and was mounted alongside the manual panel. A television control panel could be attached in the place of the manual panel when using the TV camera on the extension mechanism. The mechanical panel contained the controls for extension and ejection. The common panel contained pointing and power controls and displays. The manual panel contained: a voltmeter to indicate intensity of photometer output; an experiment select switch; a switch for Experiment S149; a switch to change PMT gain; controls and displays for filter wheels; FOV wheel; PMT shutter; PMT cap; camera operation; internal automatic sequencing, and a switch to start automatic programmer operation.

(3) Automatic programmer. The automatic programmer (AP) permitted the automatic operation of the photometer head and pointing system functions. Camera sequencing was interrelated with the pointing system so that a photograph was taken evey 11.25 degrees in trunnion position and every 45 degrees in shaft position, or, if the mount was stationary, (Mode 1) at each filter change. Two different exposure durations were used, 2.375 seconds and 0.625 second, to accommodate the anticipated light levels versus the photometer FOV selected. Automatically controlled exposures by the 16mm camera could be halted at any time (and for any length of time) during an automatic scanning sequence by moving the auto camera two-position switch to the OFF position. Seven different scanning or control modes could be selected. The number of control mode repetitions could also be selected.

An orbital-period-adjust could be set to interrupt the scanning program after each sequence in a multi-sequence scan series. A counter started the subsequent sequence one orbit later, and this procedure continued orbit-by-orbit until the selected number of sequential observations was completed. The orbital period counter digit settings enabled internal timer adjustment (between 88 minutes 8 seconds and 96 minutes 24 seconds) in 8-second increments to match the orbital period.

The control mode number, the sequence (repetition) numbers, and the orbit period numbers were entered through the programmer control panel by manual forward-or-reverse, push button stepping of rotatable wheels with octal unit indications. A panel indicator light was ON whenever the experiment was controlled by the AP. The upper and lower trunnion and shaft limits for the scan mode patterns were entered into the programmer by twelve push button wheels.

(4) Extension rods. The photometer head was deployed through the SAL by extension rods which were attached to the extension mechanism through the mechanical panel and manually pushed outward. There were three different extension rod types: an "A" rod; five "B" rods; and a "C" rod. The "A" rod was attached first, the "B" rods next, and the "C" rod last.

(5) Crank handle. A crank handle was used to stress the "C" rod by a screw-type extension to tension the entire extension mechanism.

(6) Carrying handle. The handle (located at the canister center-of-gravity) was used to lift the photometer system from the stowage container in zero-g. It was demounted and attached to each extension rod for handling during rod attachment and extension. It provided a mechanical stop to prevent each rod from being extended too far to permit attachment of the next rod.

(7) Eject tube. An eject tube was provided for use when the extension mechanism could not be retracted. The entire mechanism external to the SAL could be ejected. The eject tube required the use of the ejection mechanisms on the mechanical control panel.

(8) Tube plug. A tube plug was provided for use when an extension rod was inadvertently pushed through the O-ring seals in the canister, causing a leak. The tube plug was used to seal the hole.

(9) Shorting plug. An electrical plug was provided for use after an AP malfunction. The AP could be disconnected from the manual panel, and the shorting plug inserted. This permitted manual photometric data gathering.

(10) Cover plate. The cover plate sealed the SAL end of the canister during launch, and protected the head during stowage.

(11) Dust Covers. Dust covers were provided for protection of the electrical connectors on the photometer head, AP, and manual panel whenever they were stowed separately on-orbit.

(12) Cables. Power and data cables connected the photometer system to the OWS power and data connectors on the wall near the SAL. These cables were to be used for the T027 Sample Array System. An identical interchangeable set was provided by experiment S183 permitting both SAL's to be used simultaneously.

(13) Photometer head. The photometer head (see figure IV-27) contained the 16mm DAC photoelectric polarimeter and sunshields.

The 16mm camera system provided sequential photographic images (of starfields, etc.) of a FOV which was collinear with and overlapped that of the photoelectric polarimeter. It included a camera lens, a Model 308A 16mm Maurer camera body and sunshield. The camera lens was an f/0.95 with a fixed aperture of 25mm and a fixed focus set at infinity. The approximate FOV was 15 degrees.

The photoelectric polarimeter measured the integrated light of all sources which entered the FOV of the system. It included a cap (containing calibration source), 2.5" primary lens, collimating lens, two six-position filter wheels, rotating polarizer, refocusing lens, PMT shutter, FOV wheel, field lens, detector package, and temperature sensors. The cap contained a promethium-activated, blended-phosphor standard light source for absolute calibration and for monitoring system performance. The 6-position filter wheels each contained five different interference filters and one open position. The filter characteristics are listed below.

Filter Characteristics

Wavelength of Maximum Transmission (Angstroms)	Half-Transmission Bandwidth (Angstroms)
4000	116 $\pm$ 10
4760	50 $\pm$ 5
5080	54 $\pm$ 5
5300	58 $\pm$ 5
5577	20 $\pm$ 3
6080	88 $\pm$ 10
6300	20 $\pm$ 3
6435	108 $\pm$ 10
7100	150 $\pm$ 15
8200	250 $\pm$ 25

The FOV wheel contained six, three and one degree FOV openings with and without neutral density filters. The detector package contained a photomultiplier tube with automatically controlled thermoelectric cooling of its photocathode, a power supply, and an output voltage differential amplifier. The PMT shutter permitted determination of PMT dark current and automatically protected against intense light sources (e.g., the sun). The detector package output and polarizer wheel position were sampled by the AM data system at 320 samples per second. The polarizer wheel rotated at two revolutions per second.

(14) Sunshield assembly. Removable sunshields were provided as a single assembly for the photoelectric polarimeter and the camera to permit observation near the sun when operating at the solar SAL. The sunshield assembly was removed when operating at the anti-solar SAL.

(15) Sunshield dust covers. Two dust covers were stowed on the canister exterior and attached to the sunshield assembly when it was stowed. A third cover was attached to the end of the sunshield at launch.

(16) Stowage container. The stowage container provided: a launch/stowage location in the OWS for the photometer system; a stowage location for the photometer head and cover plate when experiment S149 was using the extension system and canister part of the photometer system; and a work area to which the photometer system canister was attached during installation and removal of film, and installation and removal of the photometer head. The stowage container was vented through an air filter for contamination protection.

(17) Support equipment. A photometer system tripod (provided by the OWS module) supported the installed photometer canister to protect the SAL and spacecraft wall from crew induced loads.

16mm film magazines were provided for the photometer head DAC. This film was stowed in the OWS film vault when not in use.

2. Experiment Operation

a. SL-1/2 Operations. The photometer system manual operations in general were performed without serious problems. Pre-mission planning required a two-man operation to transport the unit to the SAL and return to the stowage container because of the photometer system's mass and size. However, the crew rapidly learned that they could handle the unit in zero-g as a one-man operation. This may have been facilitated by the carrying handle location near the unit center of gravity.

The only manual operations problem was associated with the backup tripod installation (see subsection I.7.a.(1)). The backup tripod was launched with the parasol sunshield in the CM for the SL-2 mission. The backup unit had never been interface-tested with the flight hardware. The crew used the flight tripod (which had been launched in the OWS) to support the parasol and used the backup tripod for the photometer. The parasol had been deployed from the backup photometer canister through the solar SAL to replace the OWS meteoroid shield. The backup tripod could not be installed in its proper position on the OWS floor at the anti-solar SAL location. The crew repositioned the tripod on the floor in a semi-permanent arrangement using bolts and nuts that had been used as launch tiedowns for other equipment. The tripod remained installed at this location during the SL-2 mission.

The SL-2 MRD baseline requirement for the T027/S073 joint observing program was 23 scans with a minimum scheduling requirement of 15 scans. The final pre-mission flight plan scheduled 11 scans. The MRD indicated that if time was available, additional scans could be

performed nearly as well from the anti-solar SAL, but had been planned from the solar SAL for convenience of scheduling. However, there were some very important scans, including contamination measurement scans with applicability to ATM experiments and scans to measure the inner zodiacal light (hopefully to the point at which it begins to blend into the outer solar corona) which could only be performed from the solar SAL.

When the parasol was deployed from the solar SAL, a new T027/S073 joint observing program was developed based on the anti-solar SAL use only, on SL-2. This new program had a priority listing of 23 scans, with a baseline requirement of 13 scans and a minimum scheduling requirement of 9 scans.

The T027/S073 photometer was first installed in the anti-solar SAL on DOY 162. Table IV-16 reflects start times and initial panel conditions for each mode performed.* A total of 11 scans were performed, some were shorter than nominal; one was extended significantly (the final mode 3d); and some mode 1's inadvertently did not have a short calibration (mode 0) performed with them, as required. The 11 scans did not agree on a one-to-one basis with the revised joint observing program priority list since performance was not scheduled until late in the mission and observing conditions of full Moon; Jupiter, Moon and Earth position; and coordination with Hawaii resulted in revised priorities as the mission progressed.

During the first mode 0a operation, the shutter closed when the photometer had the sunlit Earth in its FOV (see subsection I.4.a). 16 trouble-shooting or malfunction procedures were undertaken since this only affected the calibration modes and only those portions that included bright sources in the FOV. This was observed throughout SL-2, but did not affect any of the primary data modes (modes 1 thru 5).

An operational anomaly occurred near the scheduled end of the last photometer operation on SL-2, when a trim burn was performed (in violation of the contamination mission rule 12-14 and MRD scheduling constraints) while the photometer was extended 7 rods. At this time, the unit had been extended for approximately 11.5 hours without trunnion motor operation and the PMT cap temperature was -42°C (approximately 11 to 14°C lower than predicted). When the crewman attempted to retract the unit, the photometer system did not automatically position the head to the retract position (mode 6). He noticed that the shaft position had increased from its idle position of 174.4 degrees to the maximum limit of 354.4 degrees. Through unusual manipulation of the shaft and trunnion switches, the crewman was successful in driving the shaft from its upper limit to the shaft retraction setting of 45 degrees. He could not appreciably change the trunnion setting from its 112.5 degree

*Refer to Reference Section for Performance Analysis Report.

TABLE IV-16. T027/S073 PHOTOMETER PROGRAMS, FIRST MISSION-INITIAL PANEL CONDITIONS

PROGRAM	Start Time MD·Hr:Min:Sec	Common Control Panel		Manual Control Panel									Automatic Programmer Panel							Remarks
		Shaft	Trunnion	Filter Wheel A	Filter Wheel B	FOV	Gain	Shutters DAC	Shutters PMT	Shutters CAP	Exper. Select	S149	Mode	Trunnion Upper	Trunnion Lower	Shaft Upper	Shaft Lower	Reps	Orbit Adj.	
0a	18:18:53:36.3 (DOY 162)	016 (19.7°)	1 0 (0°)	0	0	0	Med	≡	≡	≡	T027/ S073	CMD	0	N/A 2	N/A	N/A	N/A	55 (45)	00	1 Shaft and trunnion settings were initially reversed. Corrected by crew at 19:20 00. 2 N/A indicates that settings do not affect the auto program. Generally the s ts are left at 000. 2-Rod Extension
0a	18 23:45:45.0 (DOY 162)	000 (0°)	016 (19.7°)	0	0	0	Med Low				T027/ S073	CMD	0	N/A	N/A	N/A	N/A	12 (10)	00	2-Rod Extension
4a	19 01:14 24.8 (DOY 163)	000 (0°)	000 (0°)	4	0	0	Med				T027/ S073	CMD	4	100 (90°)	000 (0°)	171 (170.2°)	000 (0°)	12 (10)	47 (9..12)	Power recycled after 8 scans in order to perform Mode 1e 2-Rod Extension
1e	19:13:55:07.3 (DOY 163)	127 (122.3°)	120 (122.5°)	0	0	0	Med				T027/ S073	CMD	1	N/A	N/A	N/A	N/A	16 (14)	00	Performed at 7-Rod Extension
1d	19:19:55:04.4 (DOY 163)	323 (296.7°)	101 (91.4°)	0	0	0	Med				T027/ S073	CMD	1	N/A	N/A	N/A	N/A	6 (6)	00	Performed at 7-Rod Extension momentum dump inhibited (19:01:00)
1a(1st)	19:20:20:00 (DOY 163)	023 (26.7°)	101 (91.4°)	0	0	0	Med				T027/ S073	CMD	1	N/A	N/A	N/A	N/A	11 (9)	00	First scan at 2-Rod Extension. Crew resets to 7-Rod Extension and resets shaft and trunnion positions.
1a(2nd)	19:21:24:12.1 (DOY 163)	176 (177.2°)	073 (83°)	0	0	0	Med				T027/ S073	CMD	1	N/A	N/A	N/A	N/A	11 (9)	00	
0a	21:21:33:53.0 (DOY 165)	000 (0°)	016 (19.7°)	0	0	0	Med				T027/ S073	CMD	0	N/A	N/A	N/A	N/A	36 (30)	00	The number of Reps was changed from 44 to 36 (GOSS voice). 2-Rod Extension
4a	22:00:47:12.8 (DOY 166)	053 (60.5°)	024 (28.1°)	1	0	0	Per				T027/ S073	CMD	4	060 (67.5°)	024 (28.1°)	325 (299.5°)	053 (60.5°)	12 (10)	47 (93:12)	2-Rod Extension
1d	22:14:55:33.1 (DOY 166)	176 (177.2°)	075 (85.8°)	0	0	0	Med	≡	≡	≡	T027/ S073	CMD	1	N/A	N/A	N/A	N/A	6 (6)	00	2-Rod Extension

TABLE IV-16. T027/S073 PHOTOMETER PROGRAMS, FIRST MISSION-INITIAL PANEL CONDITIONS (CONCLUDED)

PROGRAM	Start Time MD·Hr·Min·Sec	Common Control Panel		Manual Control Panel									Automatic Programmer Panel							Remarks
		Shaft	Trunnion	Filter Wheel A	Filter Wheel B	FOV	Gain	Shutters DAC	Shutters PMT	Shutters CAP	Exper. Select	S149	Mode	Trunnion Upper	Trunnion Lower	Shaft Upper	Shaft Lower	Reps	Orbit Adj.	
2c	22:19·15:29.5 (DOY 166)	223 (206.7°)	117 (111.1°)	0	0	0	Med	≡	≡	≡	T027/ S073	CMD	2	117 (111.1°)	C16 (19.7°)	265 (254.5°)	223 (206.7°)	2 (2)	00	Momentum dump inhibited (18:39:00) 2-Rod Extension
4a	22:21:05·57.4 (DOY 166)	100 (90°)	030 (33.8°)	1	0	0	Med				T027/ S073	CMD	4	060 (67.5°)	30.0 (33.8°)	300 (270°)	100 (90°)	12 (10)	47 (93:12)	2-Rod Extension
3d	23:09:55:02.9 (DOY 167)	140 (135.0°)	113 (105.5°)	0	0	0	Med				T027/ S073	CMD	3	N/A	N/A	210 (191.5°)	140 (135.0°)	7 (7)	47 (93.12)	Performed at 2-Rod Extension.
3d	23.21:43:03.6 (DOY 167)	174 (174.4°)	120 (112.5°)	0	0	1	Med	≡	≡	≡	T027/ S073	CMD	3	N/A	N/A	250 (236.5°)	174 (174.4°)	12 (10)	47 (93.12)	Performed at 7-Rod Extension. FW-1 was recycle position from previous 3d mode. The shaft upper limit was changed from 250 octal to 234 octal (219.4°) at DOY 167, 22:45:0 GMT. FOV was changed from position 1 to position 0 at DOY 167, 22:48:00 GMT. FOV was changed back to FOV1 at DOY 168; 07:50:00 GMT (GOSS VOICE)

position, to its retract position. The AP was disconnected and the shorting plug put in place on the manual panel. At this point it was thought that the trunnion motor, having not operated for over 11.5 hours, was extremely cold and exhibiting "cold start" symptoms. In an effort to warm the trunnion motor, the crewman was directed to retract the unit to a two-rod position where it would be nearer the relatively warm spacecraft. While doing this, the crewman accidentally retracted the unit too far, and tapped the photometer head against the spacecraft exterior. He then noted that the trunnion had moved to the approximate 013 position (which was a normal automatic stop position) whereupon he commanded it to the 000 position and retracted it. Subsequent stowage operations appeared normal. See paragraph 7 for further discussion of this anomaly.

The experiment was operated on six different days; was exposed to space vacuum for approximately 132 hours; and gathered data for 14 hours and 37 minutes.

Experiment S149 was installed on the T027/S073 extension mechanism and extended through the anti-solar SAL on DOY 171. Power was applied and the temperatures were telemetered to the ground. The S149 was opened and closed by ground command to verify proper operation on DOYs 171 and 172. The S149 experiment was opened after the SL-2 CM left the Skylab OA and remained exposed between missions SL-2 and SL-3. The T027/S073 extension mechanism operated normally for experiment S149 operations.

b. SL-3 Operations. The S149 Particle Collection experiment was retracted from the anti-solar SAL and removed from the extension mechanism on DOY 213. The photometer head was re-installed and a malfunction procedure performed to verify the photometer system operational integrity.

The procedure consisted of: a visual inspection of the orientation drive mechanism and photometer head for damage; a verification that the control panel cables were attached with connectors fully engaged; and a replacement of the common-to-manual control panel cable, if required. No damage was reported and the cable was not exchanged. It was reported later in the mission, however, that the connector on the manual panel side of the common-to-manual cable, was 30 degrees away from the locked position. The crewman reported he fully locked the connector during this malfunction checkout.

The photometer was then re-installed at the SAL. The flight tripod assembly (located under the parasol canister) was transferred from the solar SAL position to the anti-solar SAL position. The backup tripod was relocated to the solar SAL to support the back end of the parasol canister. This interchange eliminated the backup tripod misalignment problem and permited ease of tripod setup and takedown at the anti-solar SAL.

The SL-3 MRD for a joint T027/S073 observing program was revised based on the anti-solar SAL use only, since the parasol would occupy the solar SAL during all Skylab missions. The MRD included a schedule of 30 baseline scans with a minimum requirement of 20 scans. The objective would be to obtain as many scans as possible if the minimum could not be accomplished.

The photometer was extended two rod lengths through the SAL on DOY 213. Table IV-17 reflects initial panel conditions for each mode performed.

During the first mode 4a performance, it was observed that the shaft position terminated at the 0 degrees lower limit setting instead of the 354 degrees upper limit. It is suspected that the crewman entered the wrong initial trunnion setting, entering 2.8 degrees (octal 02) instead of 5.6 degrees (octal 04). This caused an additional scan about the shaft axis and resulted in the photometer looking at a slightly different portion of the celestial sphere.

The mode 4a program was prematurely terminated at the end of the second performance. The crewman inadvertently entered octal 02 in the REPS indicated instead of 12 (the SL-3 checklist value). Since the crew was in a sleep period at this time, it was not possible to restart the program until the following morning of DOY 214.

The crewman attempted to change filter wheel A to the 3 position and restart program 4a at approximately 1130 GMT of DOY 214. He reported that when he cycled power from OFF to ON, the panel lights would go off after about three seconds (see subsection I.7.b.). While the panel lights were off and the power switch was ON, all real-time telemetry was lost except for the PMT, calibration source and filter wheel temperatures.

Malfunction procedures were performed in an attempt to restore normal photometer operation. The AP was replaced with the shorting plug, the trunnion was moved three or four bits and the lights went off for the last time. From this time on, the power situation appeared normal; however, the shaft position of the head could not be changed from a setting of 354.4 degrees. A requirement for photometer retraction was that the shaft position must be either 45, 135, 225, or 315 degrees.

Numerous malfunction procedures were performed in an attempt to restore normal shaft operation. They were all unsuccessful.

It was decided to continue photometer operation during the troubleshooting period for those modes that did not require a shaft scan capability. Modes 1a, 1b and 2b, were performed during this time. It was necessary to re-synchronize filter wheel A due to the many power on/off cycles, in this time frame.

TABLE IV-17. T027/S073 PHOTOMETER INITIAL PANEL CONDITIONS, SL-3

Event (Flight Plan)	Start Time MD hr min sec	Common Control Panel		Manual Control Panel									Automatic Programmer Panel							Remarks
				Filter Wheel		FOV	Gain	Shutters			Exper. Select	S149	Mode	Trunnion		Shaft		Reps	Orbit Adj.	
		Shaft	Trunnion	A	B			DAC	PMT	Cap				Upper	Lower	Upper	Lower			
Malfunction, S073	05:19:45:00 through 05:20:00:00	040 (45°)	000 (0°)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	The Common Control Panel was initially set up for retraction of S149, Particle Collection. The S149 experiment was removed from the UXM/orientation drive mechanism on 05:14:19:90
Preparation S073 PR-1	05:20:00:00 through 05:20:10:00 (approx.)	040 (45°)	000 (0°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	4	026 (28.1°)	002 (2.8°)	374 (354°)	000 (0°)	12 (10 times)	See PAD	Initial panel conditions for the photometer are per SL-3 Checklist and are subject to change per crew PAD.
Extension S073 EXT(A)	05:20:45:00 through 05:21:00:00 (approx.)	040 (45°)	000 (0°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	4	024 (28.1°)	002 (2.8°)	374 (354°)	000 (0°)	12 (10 times)	See PAD	Initial panel conditions for the photometer are per SL-3 Checklist. After photometer extension, the Common Control Panel initial shaft and trunnion settings could be changed to agree with the SL-3 Checklist: • Shaft 000 (0°) • Trunnion 002 (2.8°) However, all checklist values are subject to change per crew PAD.
Program S073-4a	Apparent: 05:23:05:14	000 (0°)	004 (5.6°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	4	074 (84.4°)	004 (5.6°)	374 (354°)	000 (0°)	12 (10 times)	47 (5.2 min)	Initial panel conditions for the photometer modified per S073 PAD 0420P Actual Program 4a operation time per orbit is 46.65 min (based on RKP 2): • Scan 44.6 min • Calibration 2.03 min The CDR apparently entered the wrong initial trunnion

TABLE IV-17. T027/S073 PHOTOMETER INITIAL PANEL CONDITIONS, SL-3 (CONTINUED)

Event (Flight Plan)	Start Time MD:hr:min:sec	Common Control Panel		Manual Control Panel									Automatic Programmer Panel							Remarks
				Filter Wheel				Shutters						Trunnion		Shaft				
		Shaft	Trunnion	A	B	FOV	Gain	DAC	PMT	Cap	Exper. Select	S149	Mode	Upper	Lower	Upper	Lower	Reps	Orbit Adj.	
																				value for the Comm on Control Panel. Suspect that trunnion was initialized at 2.8° instead of 5.6°. The 2.8° trunnion setting is derived from the SL-3 Checklist. This situation will cause the programmer to step one additional increment in trunnion at the lower limit, and the shaft to terminate at 0° instead of 354°. Consequences of this action are: • The program will terminate with the photometer looking at a slightly different portion of the celestial sphere. • All subsequent repetitions after the first scan will be within shaft and trunnion limits, but shaft will be opposite the intended programmed limit (when indicating 0°, it should be registering 354°). The CDR inadvertently entered octal 02 in Reps indicator instead of SL-3 Checklist value of 12. This situation prematurely terminates Program 4a after the second experiment repetition is accomplished. Crew error. Crewman did not configure Mode Select

TABLE IV-17. T027/S073 PHOTOMETER INITIAL PANEL CONDITIONS, SL-3 (CONTINUED)

Event (Flight Plan)	Start Time MD hr:min:sec	Common Control Panel Shaft	Common Control Panel Trunnion	Manual Control Panel Filter Wheel A	Filter Wheel B	FOV	Gain	Shutters DAC	Shutters PMT	Shutters Cap	Exper. Select	S149	Automatic Programmer Panel Mode	Trunnion Upper	Trunnion Lower	Shaft Upper	Shaft Lower	Reps	Orbit Adj.	Remarks
Malfunctions, S073	06:11:38:00 (approx.) through 07:01:40:00 (approx.)	000 (0°)	004 (5.6°)	3	0	0	Med	bp	bp	bp	T027/S073	CMD	4	074 (F4.4°)	004 (5.6°)	374 (354°)	000 (0°)	02 (2 times)	47 (5.2 min.)	Experiment 1 and 2 switches to position C-C (OWS panel 617). Real time data lost until 06:00:42:13. Restart of Program 4a occurred at 06:11:33:00. Cap Comm directed CDR to ensure that FW A is at position 3 before restart of program.
Program S073-1b	Indicated (voice) Calibration: 07:13:43:00 (approx.) 07:13:47:00 (approx.)	N/A	N/A	0	0	0	Med	bp	bp	bp	T027/S073	CMD	0	N/A	N/A	N/A	N/A	01	00	One calibration sequence (Program 0a) is normally performed before a Mode 1 operation. The calibration period is 2.03 min. See S073 PAD 0742A.
	Apparent Scans: 07:13:53:29	As is 375 (355.8°)	002 (2°)	0	0	1	High	bp	bp	bp	T027/S073	CMD	1	N/A	N/A	N/A	N/A	27 (23 times)	00	Initial panel conditions for the photometer were modified per S073 PAD 0742A. The Automatic Programmer Camera Enabler switch was ENABLE. Actual Program 1b operation time per scan repetition is 2.05 min.
	Apparent Recalibration: 07:15:17:22	As is 375 (355.8°)	002 (2°)	0	0	1	Med	bp	bp	bp	T027/S073	CMD	1	N/A	N/A	N/A	N/A	27 (23 times)	00	
Malfunctions, S073	07:15:57:33 through 07:15:58:17	As is 375 (355.8°)	002 (2°)	0	0	1	Med	bp	bp	bp	T027/S073	CMD	1	N/A	N/A	N/A	N/A	N/A	N/A	The CDR cycled the T027/S073 power switch to ON, two times, once at 07:15:57:33 and once at 07:15:58:14.

TABLE IV-17. T027/S073 PHOTOMETER INITIAL PANEL CONDITIONS, SL-3 (CONTINUED)

Event (Flight Plan)	Start Time MD hr min sec	Common Control Panel		Manual Control Panel									Automatic Programmer Panel							Remarks
				Filter Wheel				Shutters						Trunnion		Shaft				
		Shaft	Trunnion	A	B	FOV	Gain	DAC	PMT	Cap	Exper. Select	S149	Mode	Upper	Lower	Upper	Lower	Reps	Orbit Adj.	
Program S073 - Ia	Actual 07:15:59:04	As is 375 (355.8°)	100 (90°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	I	N/A	N/A	375 (355°)	375 (355°)	11 (9 times)	00	Initial panel conditions for the photometer were modified per S073 PAD 0746. One calibration sequence (Program Oa) is normally performed before a Mode I operation. The calibration period is 2.03 min. Actual Program Ia operation per scan repetition is 2.05 min.
Program S073 - Ia	Actual 07:17:28:15	As is 375 (355.8°)	104 (95.6°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	I	N/A	N/A	375 (355°)	375 (355°)	50 (40 times)	00	Initial panel conditions for the photometer were modified per S073 PAD 0746. One Program Oa calibration sequence is normally performed before a Mode I operation. The calibration period is 2.03 min. Actual Program Ia operation per scan repetition is 2.05 min.

TABLE IV-17. T027/S073 PHOTOMETER INITIAL PANEL CONDITIONS, SL-3 (CONCLUDED)

Event (Flight Plan)	Start Time MD hr min sec	Common Control Panel Shaft	Common Control Panel Trunnion	Manual Control Panel Filter Wheel A	Filter Wheel B	FOV	Gain	Shutters DAC	Shutters PMT	Shutters Cap	Exper. Select	S149	Automatic Programmer Panel Mode	Trunnion Upper	Trunnion Lower	Shaft Upper	Shaft Lower	Reps	Orbit Adj.	Remarks
Malfunctions, S073	07:21:05:00 (approximately) through 07:22:40:00 (approximately)	As is, 375 (355.8°)	100 (90°)	0	0	0	Med	bp	bp	bp	T027/ S073	CMD	1	375 (355°)	375 (355°)	N/A	N/A	11 (9 times)	00	The initial panel conditions for the photometer were modified per S073 PAD 0743, operations to commence at 07:21:34:00. However, the above Program 1a operation was never accomplished because of implementation of malfunction procedure through 10.
		As is, 375 (355.8°)	002 (2.8°)	0	0	1	High	bp	bp	bp	T027/ S073	CMD	1	375 (355°)	375 (355°)	N/A	N/A	11 (9 times)	00	Initial panel conditions were set up per S073 PAD 0743A. However, the S073-1b programs were aborted in favor of performing mal-function procedures 8 through 10.
Program S073-2b	Apparent, 07:23:50:50	As is 375 (355.8°)	000 (0°)	0	0	1	High	bp	bp	bp	T027/ S073	CMD	2	104 (95.6°)	000 (0°)	375 (355°)	375 (355°)	11 (9 times)	47 (5.2 min)	Original start time for Program 2b was scheduled for 2215/2353 per PAD 0743. However, Cap Comm directed the CDR to reschedule the program start time for 2348/2353. The program repetitions (Reps) were changed from 10 (octal 12) to 9 (octal 11). The total Program 2b scan time is: • REP 1 8.7 min • REPS 2-9 73.3 min 82.0 min or 1.36 hr

After exhausting all troubleshooting schemes to restore normal shaft drive mechanism operation, the extension mechanism and photometer head were ejected from the SAL at approximately 1402 GMT of DOY 216. The photometer canister and control panels were stowed.

The photometer was operated on DOYs 213 through 216. Data was gathered for five hours and 48 minutes; five different scans were performed; and data was taken during nine orbits.

Later in the SL-3 mission, seven frames of S063 film were exposed to obtain photographs of the Gegenschein for the S073 PI. The hardware included the T025 canister, with the occulting discs removed, mounted to the anti-solar SAL and photographs taken with the S063 35mm Nikon camera. The success of this photography led to the baselining of additional similar photography on SL-4, on a low priority basis. (See sub-section J.)

3. Experiment Constraints. All experiment constraints were successfully met during the SL-1/2 and SL-3 missions except for the one requiring the photometer to be inside the SAL with the SAL door closed during, and for at least 30 minutes after, any hot gas thruster firing. The photometer was deployed seven rods during the trim burn mentioned earlier. This was done with the PI's and Corollary Flight Controller's approval.

4. Hardware Performance.

a. SL-1/2 Performance. The hardware performed satisfactorily on the SL-2 mission with two major exceptions. These were the backup tripod misfit at the anti-solar SAL location and the photometer head failure to return to a retract position. There anomalies are discussed in paragraph 2.

Light leaks around the PMT cap caused the PMT shutter to close during calibrations when the head was pointed at the sunlit Earth or other bright object (see paragraph 2.). It was first suspected that colder than predicted temperatures might have caused minor binding in the cap actuation mechanism thus causing the cap not to close completely light tight. This was refuted when a light leak occurred at a cap temperature of +69°F.

Investigations into the photometer head testing history revealed that no light leak tests were made with the solar sunshield removed. This configuration was that used for the anti-solar SAL operations. Between SL-2 and SL-3, a light leak test was performed in this configuration on the flight backup and engineering development model (EDM) heads. It was concluded from these tests that the head was not light tight with the PMT cap closed and PMT shutter open when the head-to-source angle was less than the sunshield's effectivity angle. It was further shown that there was more light leakage when the head was in the anti-solar configuration. The PMT shutter was designed to protect the PMT

by closing whenever a bright light condition occurred, such as scanning the sunlit earth or spacecraft. Thus, the shutter closures during the Mode 0 calibration sequences were normal performance and not due to a failure or anomaly, although they had not been expected preflight.

b. SL-3 Performance. The shaft drive mechanism failure was the only major anomaly that occurred on the SL-3 mission. Unfortunately, it resulted in the eventual loss of the experiment. A detailed discussion of this failure is given in paragraph 2. The filter wheels became unsynchronized during power on/off cycles performed as part of the shaft troubleshooting procedures. A malfunction procedure was performed by the crew which successfully resynchronized the filter wheels.

After the photometer was ejected, it was decided to investigate a re-supply of the backup photometer system for SL-4. Two approaches were considered because of the possible SL-3 rescue mission.

Concepts for a shortened photometer boom were proposed, since the available space in the SL-4 CM was quite limited. Several ideas were considered, but all were basically limited to a 2 rod design, with a main canister that was half the length of the original photometer canister. This approach never advanced beyond the sketch stages, due to the low priority given the T027 experiment on the SL-4 stowage list.

The second approach was to make whatever modifications were necessary to the photometer backup system, so that it could be stowed in the SL-3 rescue mission CM if it were flown. Since there was more space available on the rescue mission, it was decided to pursue this course.

The backup system refurbishment took place between August 9 and September 12, 1973. It was necessary to obtain a new canister since the backup flight canister had been removed and used for the Skylab parasol. It was decided to reassemble the backup system using the EDM canister. A drive motor circuit by-pass modification was incorporated into the system providing switches on the common control panel to directly power the shaft and trunnion motors without going through logic and relay circuitry. The refurbishment removed the bracketry from the canister top to reduce the launch volume and weight.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission with the exception of the backup tripod installation as discussed in paragraph 2.

6. Return Data. Data returned to the PI's consisted of users tapes (raw telemetry magnetic tapes), real time strip charts, crew transcripts, and motion pictures of the photometer deployment. Some telemetry data was lost due to improper configuration of switches on panel 617. This panel had to be properly configured in order that all the data channels from the photometer would be recorded. (Other configurations were used to record data from the biomedical experiments.)

The 16mm DAC photographs (one 140 ft magazine) were returned from the SL-2 mission; however, no 16mm film was returned from the SL-3 mission as it was in the photometer head when the head was ejected. Seven frames of S063 35mm film (Kodak type 2485) with photographs of the Gegenschein were returned to the S073 PI from SL-3.

7. Anomalies.

a. SL-1/2. The major anomalies were the backup tripod misfit at the anti-solar SAL and photometer head failure to return to a retract position; probably due to an open connection at the P9 connector.

(1) Tripod Problem. The installation problem with the serial number 2 tripod, was twofold.

First, a tilt down and shift to the right (reported by the crew) was apparently caused by interchanging legs #2 (long) and #3 (intermediate length) to effect such a tilt condition. The tripod baseplate was designed to be parallel to the floor if all three legs were installed in their proper receptacles. Figure IV-33 shows the legs and tripod head assembly.

Second, the tripod adjusting mechanism was improperly positioned on the adapter plate as shown in closeout photographs at KSC (compare the #1 leg position with the plate centerline in figures IV-33 and IV-34). The adjustment mechanism is shifted approximately two inches to the right (looking into the SAL).

The problem was efficiently resolved when the crew bolted the legs to the OWS floor in a new position and provided an effective semipermanent tripod interface to the experiment bracket for the remainder of the SL-2 mission.

Subsequent analysis showed that the serial number 2 tripod would work properly at the solar SAL. The SL-3 crew was therefore directed to interchange the two tripods to permit ease of tripod setup and takedown at the anti-solar SAL.

(2) Retraction Problem. The Mode 6 retraction problem encountered on SL-2 (See paragraph 2.) is believed to be the result of a relay being actuated near the end of the trim burn. This would have caused the shaft drive to go to its upper limit (octal position 374) when the shaft and trunnion switches were in the OFF position. The indication that the relay was actuated is evident by the shaft and trunnion switch positions required to start and stop shaft movement. It was necessary to utilize the switch interlock feature (trunnion switch in DECR position) to keep the shaft stationary. Otherwise the shaft would return to its upper limit of octal 374. Later after trunnion decreased from 120 to 117 octal, a trunnion switch setting of INCR or DECR would stop shaft motion.

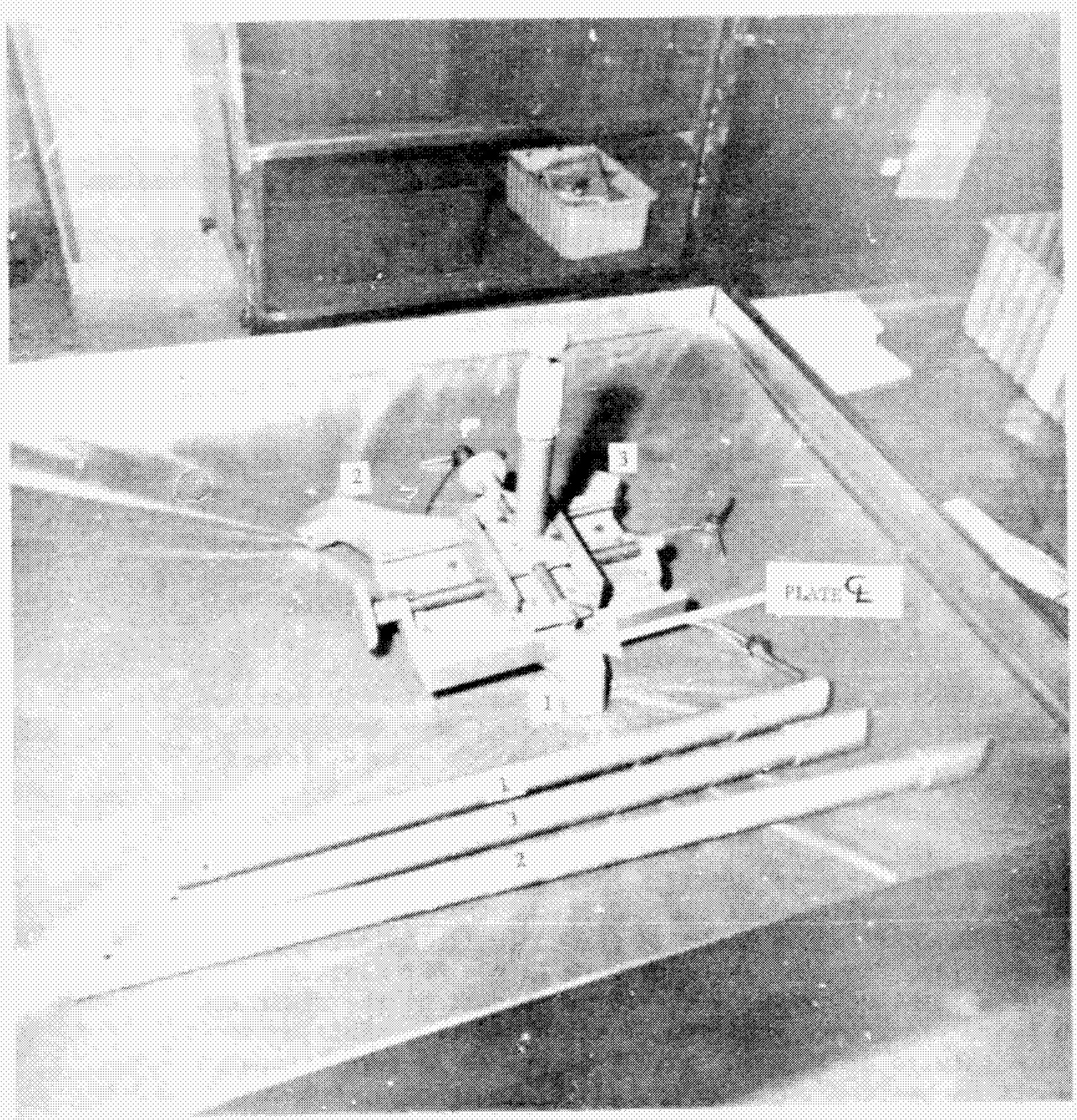

FIGURE IV-33. BACKUP FLIGHT UNIT TRIPOD (SL-2 LAUNCH)

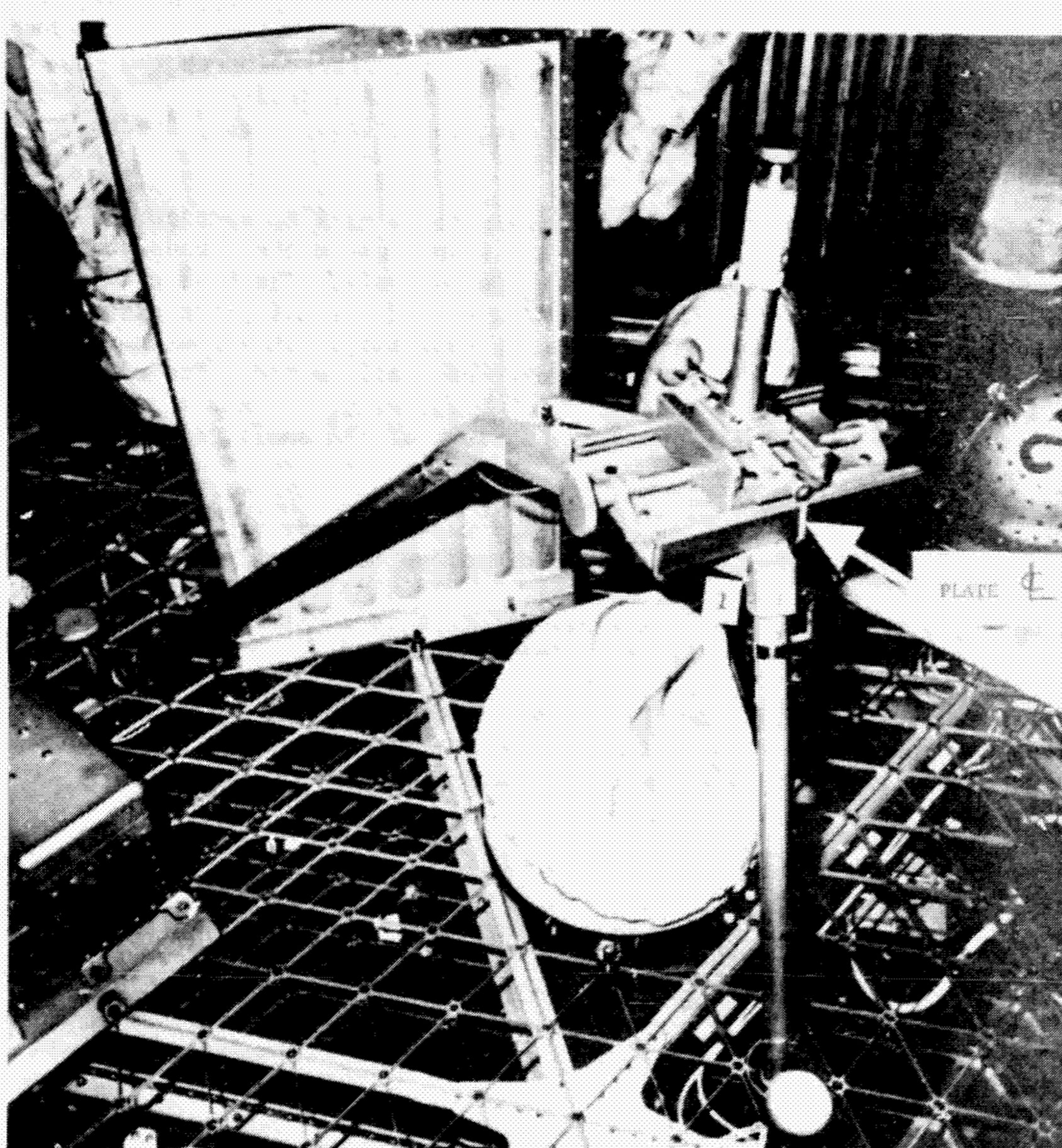

FIGURE IV-34. FLIGHT UNIT TRIPOD (SL-1 LAUNCH)

The relay could be actuated by two open circuits in the gimbal drive logic. The two open circuits could have resulted from the P9 connector (on the common-to-manual jumper cable) not being fully mated and locked, although the problem could have been at other circuit locations, such as the P8 connector on the common panel end of the same jumper cable or circuitry inside the manual panel.

The fact that the relay appeared to actuate immediately after trim burn termination cannot be overlooked. It was possible that an OWS vibration caused by the burn could have loosened an already unlocked connector P9 which resulted in the two open circuits. Later in the trouble shooting period, prior to or during the retraction to the two-rod configuration, and bumping against the OWS side, additional vibrations may have closed the open circuits freeing the relay. These effects were reproduced by ground tests.

A backup jumper cable and a tool (to be used to extract the flight jumper cable from the common panel and remate the backup cable) were launched on SL-3 as a result of this analysis. The SL-3 crew was instructed to inspect the connection when first using the photometer and to replace the jumper cable if necessary. It was discovered upon inspection, that the cable was only partially mated. The crew remated and locked the P9 connector. Subsequently, the shaft and trunnion operated normally until the failure of the shaft drive mechanism.

b. SL-3. The major anomaly was the power drop-out which led ultimately to a failure in the shaft drive mechanism and subsequent ejection of the photometer head and boom. This malfunction was probably caused by a failure within the shaft motor drive logic circuit or shaft drive relay driver circuit. The failure had an approximately six-hour transient period during which it overloaded the 5V power supply and caused 5V and 29.5V power to drop out approximately three seconds after each power recycle. After the failure had opened the shaft motor drive circuit, the shaft could not be driven from its high limit position.

A detailed data review conducted subsequent to publication of a failure report* has not changed its basic failure analysis conclusions. Some additional ground tests were performed as recommended in the report to determine if the SL-2 mission anomaly would cause overstress (overvoltage or overcurrent conditions) that could result in the SL-3 mission anomaly. No such overstress on the motor-drive logic or motor-drive relay driver circuit components existed under simulated mission operation of the EDM.

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*Refer to Reference Section for test report.

Prior to the SL-4 launch, a Common Panel and Relay Driver Assembly Removal Procedure was generated, approved for SL-4 data package inclusions, and launched on the SL-4 CM. The removal operation was not performed during the SL-4 mission due to the crew time required and low priority for failure analysis activity.

The exact failed element and its failure mode will never be identified since the two subassemblies (either of which may have contained the failed element) were not returned to earth for failure analysis.

J. Experiment S073 - Gegenschein/Zodiacal Light (SL-4)

The Principal Investigator for Experiment S073, Gegenschein/ Zodiacal Light, is Dr. J. Weinberg, State University of New York at Albany, Albany, New York. In its configuration on SL-4, S073 used equipment supplied by other experiments.

1. <u>Experiment Description</u>. Low brightness target regions for this experiment were photographs from spacecraft beginning with the last Project Mercury flight. As emulsion sensitivities were improved and faster-lens cameras qualified for flight, results improved. Very good data were obtained from lunar orbit on the last four Apollo flights; however, all these attempts had to contend with Command Module window transmission limitations and changes in vehicle attitudes during the long exposure times. On SL-3, a procedure for long-exposure photography of low-brightness sources had been developed using S063's 35mm Nikon camera together with the T025 canister. This assembly was mounted on the anti-solar SAL to photograph the Gegenschein, which was aligned with the anti-solar axis whenever Skylab was in the solar-inertial attitude.

a. Objectives. The objectives were to measure the surface brightnesses of five types of extended astronomical sources in their visible and ultraviolet light using photometric photography and to measure the scattered light background observed from the spacecraft by photometric photography.

The low-brightness sources to be studied were the Gegenschein region, zodiacal light perpendicular to and in the ecliptic between 90° and 120° from the sun, regions in the plane of Comet Kohoutek's orbit, the earth-moon libration regions L_4 and L_5, and galactic regions. These galactic regions included interstellar light in the Milky Way galaxy and low brightness extensions associated with individual and clustered galaxies. The light from the Gegenschein, from zodiacal light and, possibly, from particle concentrations at the libration regions arises from sunlight scattered by innumerable microscopic particles of interplanetary dust. The measurement of surface brightness of these regions was to provide information on concentrations and locations of these particles. In addition, the collection of data over a span of many weeks was to confirm or deny the existence of short term variations in brightness. The galactic photography took advantage of the dark night sky available from the Skylab orbit to detect the faintest outer limits of galaxies. Ground photography of this nature, even from the Palomar telescope, is limited by the brightness of the earth's atmosphere at night.

The determination of the scattered light background as observed from manned spacecraft is critical to observations planned for future LST and Shuttle Sortie missions. Therefore, contamination photography was to be undertaken to replace that lost with the loss of the T027 photometer. Such photography was to measure the total scattered light

background as well as discrete particles generated by spacecraft operation. The only measurements of this type previously performed aboard Skylab had been made on separate passes by T027. The photographic data was to differentiate between the brightness attributed to the general background and that due to discrete particles.

b. Concept. On SL-4, in addition to further Gegenschein photography similar to the SL-3 photography, the same equipment as used on SL-3 was to be used with the S019 Articulated Mirror System (AMS) to view regions in the celestial annulus between 90 and 120 degrees from the sun.

c. Hardware Description. There was no dedicated experiment hardware assigned to the S073 operations.

A revised SL-4 MRD for experiment S073 reflected the T025 canister use (occulting discs removed) mounted directly to the anti-solar SAL to photograph the Gegenschein or mounted to the S019 AMS to photograph the other targets. When using the S019 AMS, the T025 canister was attached with the S063 adapter. The photography was taken with a 35mm Nikon camera, sometimes using the UV lens.

2. Experiment Operation. The MRD described 36 functional objectives (FO's), each FO being one night pass. Only 17 of these FO's were baselined; the other 19 being listed as candidates. The photographs for the S073 PI were of the Gegenschein region, the zodiacal light perpendicular to and in the plane of the ecliptic between 90° and 120° from the sun, regions in the plane of Comet Kohoutek's orbit, and the earth-moon libration regions L_4 and L_5. Photographs of scattered light from contamination particles and photographs of galactic regions were included in these FO's for other investigators.

Experiment operations are summarized in table IV-18. During each night pass, photographs were normally taken of more than one S073 target. Since the FO's were written on a basis of only one or two targets being photographed per pass, there was not an exact correlation of actual FO's accomplished with the MRD FO's.

All photographs were taken with the 35mm Nikon serial number 02 camera, using Kodak type 2485 film. The experiment was run on a total of 17 night passes and a total of 96 photographs were taken versus an MRD baseline requirement of 17 night passes and 85 photographs.

3. Experiment Constraints. The experiment constraints were successfully met during the SL-4 mission except that the CMG's were not inhibited as required on DOY 030 during the operations beginning at 1910 until 1944 GMT. This may not have been a serious problem since the target region of zodiacal light was so broad and smearing might be accounted for in the data reduction.

TABLE IV-18 S073 PHOTOGRAPHY DURING SL-4 MISSION

DOY	NUMBER OF PHOTOGRAPHS	SETUP	LENS	TARGETS
344	9	T025/AMS	VIS	4 Contamination 2 Lunar Libration 3 Comet Plane
356	9	T025/AMS	VIS	4 Contamination 2 Galaxy 1 Comet Plane 1 Lunar Libration 1 Zodiacal Light
361	7	T025/AMS	UV	2 Contamination 1 Lunar Libration 2 Galaxy 2 Zodiacal Light
361/362	14	T025/AMS	VIS	7 Contamination 2 Lunar Libration 3 Galaxy 2 Zodiacal Light
001	4	T025/AMS	UV	2 Contamination 2 Galaxy
001	2	T025/AMS	VIS	2 Galaxy
019/020	11	T025/AMS	UV	6 Contamination 2 Zodiacal Light 3 Lunar Libration
020/022	11	T025	VIS	4 Contamination 7 Gegenschein
022	5	T025	UV	2 Contamination 3 Gegenschein
023	12	T025	VIS	4 Contamination 8 Gegenschein
028/030	8	T025/AMS	VIS	1 Galaxy 3 Lunar Libration 3 Zodiacal Light 1 Ecliptic Pole
030	4	T025/AMS	UV	4 Galaxy

4. Hardware Performance. The hardware appeared to perform normally during the mission. However, when the photographs were developed they were all found to be out of focus. This was true for all photographs taken with the 35mm Nikon camera serial number 02.

5. Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. Ninety-six frames of 35mm Kodak type 2485 film were returned.

7. Anomalies. The Nikon camera (serial number 02) used for all the S073 SL-4 photography was used to take operational photographs, to take some S063 photographs, and for all T025 photographs after the first EVA. The operational photographs on the first roll of film exposed on SL-4 with this camera were in focus; however, all subsequent photographs were out-of-focus. The out-of-focus condition appeared to vary from frame to frame, although all frames were out of focus. From study of the objects appearing in the photographs (e.g., the S019 AMS, interior of the T025 canister or the T025 occulting discs) the camera appeared to be focussed at approximately 3 to 5 feet rather than infinity.

Since this camera was not returned from orbit, no failure analysis could be performed. Ground tests were performed at JSC to attempt to simulate the results. The closest duplication of the results was obtained by removing the pressure plate from the camera and allowing the film to float in and out of the film plane. It is suspected that the pressure plate was missing from the Nikon 02 camera and if revisit to Skylab occurs it would be desirable to retrieve this camera. The crew did not notice any missing pressure plate, nor was one found on-orbit. Normally, loose equipment of this type would be found on the screens over the air circulation ducts. The crew did note that the camera back did not completely close and, in fact, they taped it shut to prevent any light leaks. If the camera is not returned, the exact cause of the problem will never be known.

K. Proton Spectrometer - Operational Instrument

The Principal Investigator for the Proton Spectrometer is Dr. Godehard Guenther, University of Alabama at Huntsville, Alabama. The Associate Principal Investigator is Dr. T. Parnell, Space Sciences Laboratory, MSFC. The instrument was developed by the Space Sciences Laboratory, with Mr. G. Detko as Engineering Manager. The electronics subsystem was built by Spacetac Corporation, Bedford, Massachusetts.

1. Instrument Description

a. Objectives. The objective was to place in orbit a self-calibrating instrument capable of measuring the energy spectrum intensity and pitch angle distribution of electrons and protons trapped in the South Atlantic Anomaly radiation belts. This was intended to provide accurate mapping of this high radiation area, and of the northern and southern "horns", all created by the earth's magnetospheric trapping of protons and electrons. Time variations of these measurements over long periods would help in the analysis of radiation belt solar modulation. This knowledge of the particles energy spectrum would aid future space programs in: the design of radiation shielding, the choice of films and film developing procedures, and the determination of crew radiation dosages.

b. Concept. The concept was to mount a high-counting-rate particle detector on the vehicle exterior enabling an unobstructed view of space. The instrument would have a 45 degree acceptance cone, being positioned along the vehicle Y-axis allowing a particle pitch angle distribution to be determined. A combination of solid-state detectors and scintillation detectors would be used, in conjunction with instrument electronics, to classify the electrons detected, 1.2 to 10 million electron volts MeV, in three discrete energy levels. Likewise, the protons detected 18.5 to 400 MeV would be distributed into eight energy levels. The instrument would contain a unique closed-loop digital calibration system that would automatically maintain accurate calibration of the boundaries between these energy levels. Two analog thermal monitors would indicate the instrument temperature so that appropriate correction factors could be applied, if necessary.

Data would be returned through the Skylab telemetry system. Real-time data would be combined with data recorded and dumped through the AM recorders. Instrument control would be maintained through the AM Digital Command System (DCS) via RF command and crew local control.

c. Hardware Description. The instrument was comprised of a detector head assembly (see figure IV-35) and an electronic subsystem installed in a thermal shroud. The instrument was shock-mounted to the S194 truss at the MDA forward end, providing a clear field-of-view within a 45 degree window of the external Skylab radiation environment.

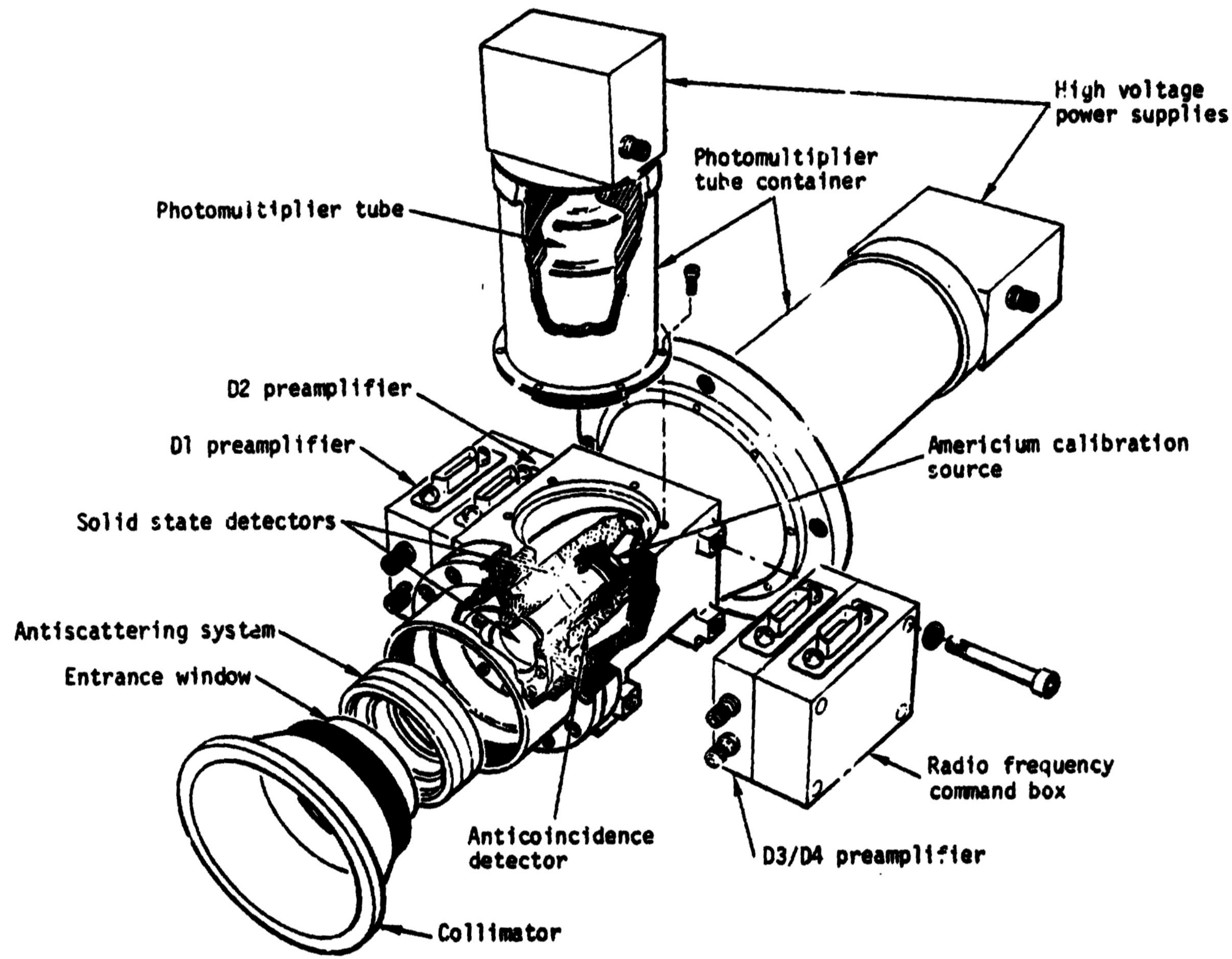


FIGURE IV-35. PROTON SPECTROMETER DETECTOR HEAD ASSEMBLY

The detector head was a directional device, composed of four detectors. Two solid state detectors (D1 and D2) and a scintillation detector (D3) were used to detect the particle's presence and energy. A cylindrical scintillation detector (D4), or shield, surrounded these detectors and was used primarily as an anticoincidence detector to create a 45 degree acceptance cone (see figure IV-35). Additionally, D4 provided a measurement of the radiation field total flux.

The electronic subsystem processed the detector data. This processing determined whether or not the particle entered the instrument through the 45 degree acceptance cone, and if the particle had, then determined if it was an electron or a proton. The instrument determined the particle's energy and classified it within one of the energy bands, adding it to the appropriate counter. The counters were read at 1.2-second intervals and presented to the telemetry system. This information was transmitted directly to the ground station in real-time, or recorded on the AM recorder for later transmission, thus enabling eventual reconstruction of the entire orbit.

The instrument was designed to operate continuously throughout each complete Skylab orbit. When the D4 detector sensed a radiation level in excess of a selected value, the instrument initiated a proton and electron counting mode of operation. The particle flux level at which the instrument switched was controlled from the ground by ATM DCS command. When the flux level decreased to a point below the selected level (typically as the Skylab emerged from the South Atlantic Anomaly) the instrument switched back to a calibrate (CAL) mode of operation. In the CAL mode, the instrument continued to count the electrons present, but used its proton energy measuring function for self-calibration. This closed-loop digital calibration technique was unique to this instrument. It incorporated the use of the radioactive isotope Americium to provide a constant-energy particle for calibration.

The instrument output consisted of analog and digital data. The analog data contained two temperature measurements (the detector head and the electronics package) and two particle-count measurements (D4 total dose, and D1/D2 accidental coincidence, used to eliminate erroneous data when a particle enters the instrument through the side coincident with one entering through the 45 degree acceptance cone). The digital data was a 12-bit word, updated 10 times per second. A complete data frame of 12 words (3 electron channels, 8 proton channels, and the D3 count) was completed each 1.2 seconds. Real-time monitoring was limited to the four analog measurements.

Instrument control was by ground command. It could be commanded on or off, or the flux threshold level where the instrument would switch from calibrate to count could be changed, via the ATM DCS system. The crew had the capability to manually turn the instrument to ON, OFF or COMMAND.

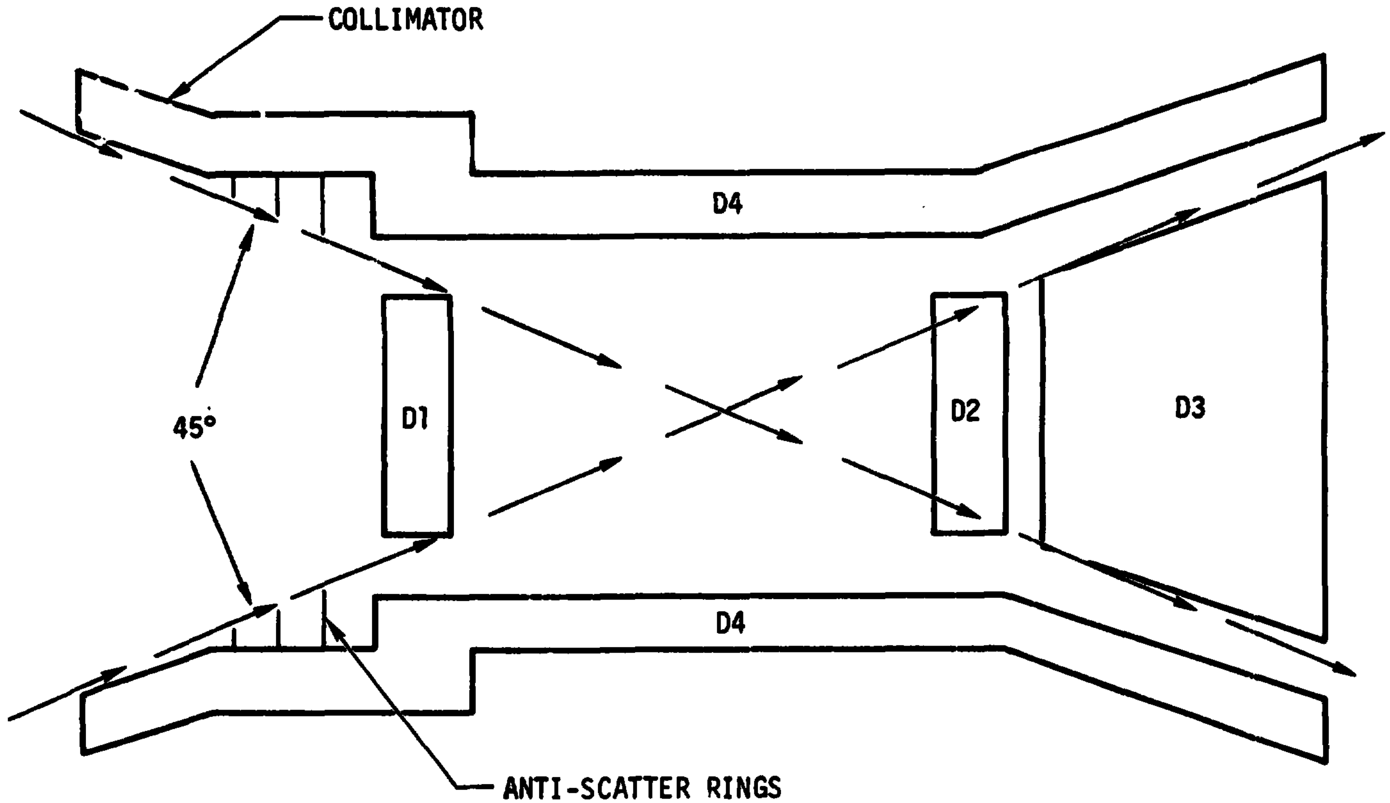


FIGURE IV-36. DETECTOR ORIENTATION

2. Instrument Operation

a. SL-1/2 Mission. The instrument was initially turned on approximately 12 hours after the SL-1 launch (approximately eight hours later than scheduled) on DOY 135 at 0530 GMT. The delay was due to the emergency activities associated with the OWS meteoroid shield loss. The delay request was acceptable because the instrument temperature was decaying slower than the prelaunch prediction. The initial instrument temperature at launch was 23°C. The instrument temperature at turn-on was -25°C, which was the minimum temperature allowed with no power applied per a mission constraint.

The first indication of operation occurred approximately five hours after turn-on, at 1030 GMT. The indication was the D4 total dose measurement peaking, as monitored in real time at the HOSC.

The first digital data were received 34.5 hours after launch, on DOY 136 at 1604 GMT and were provided by KSC. Due to the time required to obtain processed digital data via regular channels, KSC assisted by real-time monitoring of passes over the KSC station (MIL). KSC processed this data with the Quick-Look Data Station (QLDS) software programs used during prelaunch testing. The data, for several passes going into or coming out of the Northern Horn Belt, showed electron count data as expected. However, the data showed abnormal operation in the calibration mode. A temperature-induced failure was determined to have caused the abnormal operation.

On DOY 138 at 1619 GMT, the instrument was forced into the count mode by ground command. On DOY 142 at 1325 GMT, a single step command was sent to place the instrument back in the calibrate mode. These actions were taken to insure operation through the South Atlantic Anomaly in the count mode. Through this period there was no data available to show that the instrument was switching automatically from calibrate to count. Verification of this automatic switching did occur on DOY 165.

b. SL-3 Mission. The operation throughout SL-3 was unchanged from SL-1/2. The proton channels were degraded (see paragraph 7) but the data were gathered and stored for post-mission analysis.

c. SL-4 Mission. The instrument was cycled off and then on, in the hope of restoring the proton channel data, with no apparent success. The data were gathered and stored for post-mission analysis. The AM signal conditioner for the temperature measurements malfunctioned resulting in the loss of these measurements.

3. Constraints. The experiment constraints were successfully met during the mission except that for corona restraint. The constraint not adhered to was intentionally overridden after due consideration. It specified that "operations of the Proton Spectrometer

will be interrupted (by power turnoff) during all CSM RCS Operations (including docking and undocking). Operation shall be initiated no sooner than 15 minutes after completion of RCS operations. Additionally, power should not be turned on within one minute of any interruption. The requested number of DCS command (358) shall be sent after each power "turn on." Lower-than-predicted operating temperatures that approached the thermal constraint limit could have resulted from removal of instrument power upon CSM undocking at the SL-1/SL-2 completion requiring that power be reapplied in violation of the corona constraint. Laboratory tests with qualification test hardware indicated that the potential for corona was less than the potential consequences associated with lower temperatures. An Action Request, AR-348, was therefore generated by MSFC to cancel proton spectrometer constraint 069 relating to the experiment turn-off to preclude corona.

4. Hardware Performance. The instrument was operated throughout all three Skylab missions, gathering data for post-mission analysis, but the lower-than-predicted temperatures affected the primary data of the instrument (see paragraph 7). Electron channel 1, D4 analog (total count) and the D3 total dose data will be evaluated. The energy measurement function of the D3 detector PM tube was significantly affected by the low temperature, as was the D2 coincidence circuitry; thus electron channels 2 and 3 and all eight proton channels are considered invalid.

During SL-4 it was determined that the proton spectrometer, even in its degraded state, was providing useful information for gamma-ray studies (as documented in a letter from the Associate Principal Investigator, Dr. T. Parnell to Mr. Jack Waite, MSFC/SL-DP, on January 17, 1974). It was stated that the output of the D3 detector in the CAL/Count Modes could be useful in the detection of transient cosmic gamma-ray events (gamma-ray bursts).

5. Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Returned Data. The telemetered data were compiled for post-mission analysis. The data were generally degraded due to the instrument failure. Only one low-level electron channel, the D4 total flux measurement, and the D3 total dose measurement were intact. All eight proton channels and the two high-level electron channels were degraded.

7. Anomalies. A failure analysis report was prepared by the Engineering Manager, dated September 20, 1973. The report summarizes the events surrounding the instrument failure, then presents the following analysis of the probable failure mechanism.

The instrument's temperature history has played a significant role in the analysis of the performance. The SL-1/2 temperature history included the following three significant time periods:

The first period was from launch through the initiation of the pitch and yaw maneuvers to control the rising temperatures in the workshop (reference figure IV-37). The temperature decayed at a rate slower than prelaunch predictions, but was approaching the constraint limit at instrument turn-on.

In the second period the vehicle was taken out of the solar inertial attitude to reduce the heating of the OWS. The pitching of the vehicle placed the instrument in the sun and the temperature rose to and stabilized at $4^{\circ}C$ ($40^{\circ}F$), for the next 8 days.

The third period began with the return of the vehicle to solar inertial for SL-2 docking (DOY 145). The temperature dropped to $-33^{\circ}C$ ($-28^{\circ}F$) in 54 hours (see figure IV-38). The temperatures remained within $\pm 5^{\circ}$ of -31° ($-24^{\circ}F$) (head) and $-25^{\circ}C$ ($-14^{\circ}F$) (electronics) throughout the SL-3 and SL-4 missions.

It is felt that the lower-than-predicted operating temperature of the instrument resulted in contraction of the RTV 615 material used to couple light from the D3 scintillator detector to the photomultiplier tube. The gap thus created effectively reduced the gain of the instrument, so that high-energy particles striking the detector were unable to produce the required electronics input. Also, the D2 coincidence circuitry was lost. It was believed that, if the instrument temperature was returned to the designed level, the gap would be closed and the instrument returned to operation.

The cause of the low operating temperature was traced to an error in the thermal analysis. A large error in the emissivity value of the thermal shroud interval surface resulted in the prediction of a higher operating temperature. The instrument did not retain as much internal heat generated by the instrument as predicted.

A thermal blanket was proposed for installation on an SL-4 EVA, to raise the instrument's temperature, but due to SL-4 resupply space and weight considerations, these efforts were terminated.

During SL-4, ground testing was performed to verify the failure mode. The information was hoped to be useful in developing a procedure for returning the flight unit to an operational state, and in assisting the post-mission data analysis. The test was performed on the backup article at Spacetac, Bedford, Mass. (the backup unit was removed from the backup MDA in St. Louis and returned after the test). The test confirmed the conclusions of the failure analysis, i.e., that raising the temperature was the only means of restoring instrument performance.

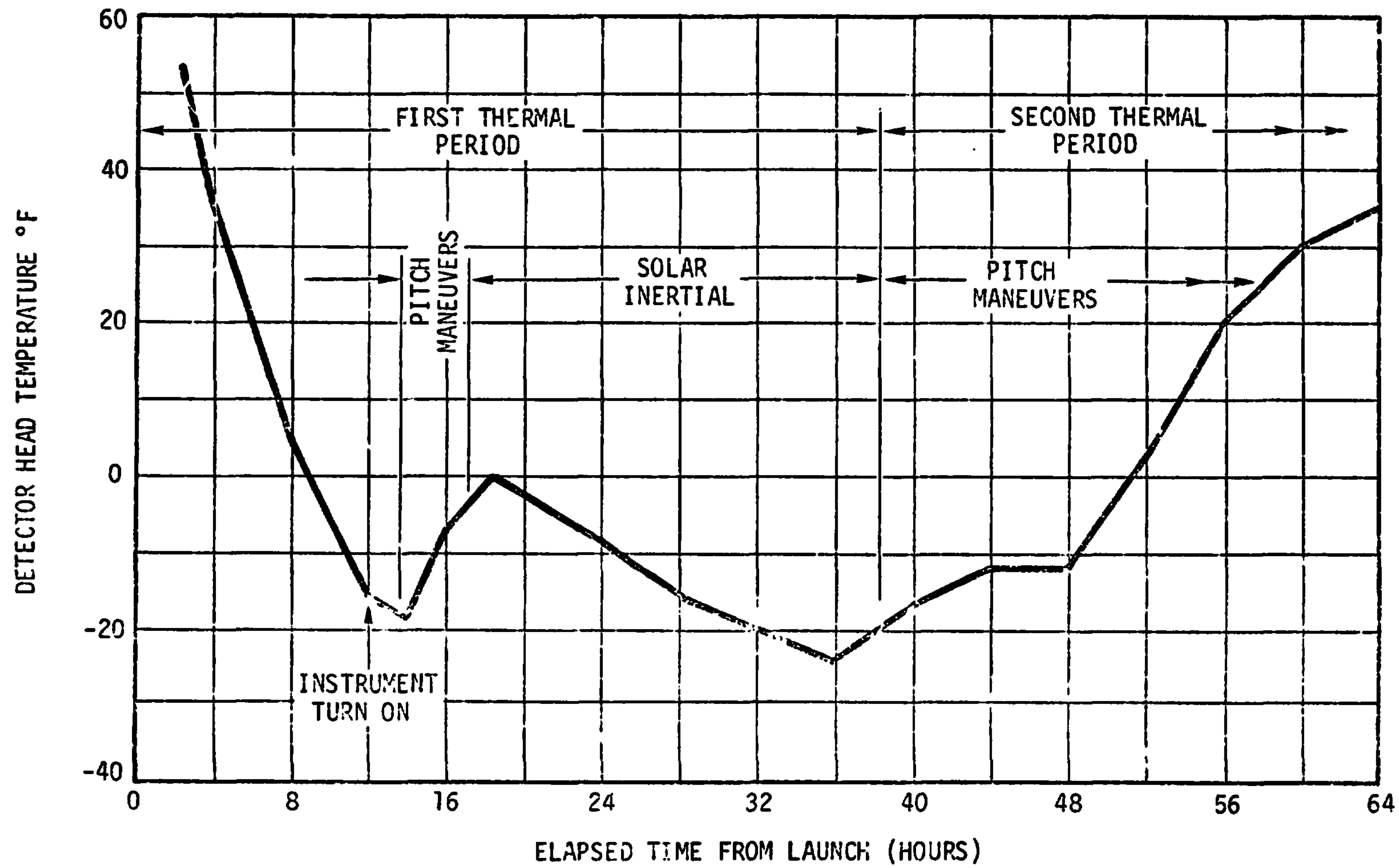


FIGURE IV-37. PROTON SPECTROMETER TEMPERATURE PROFILE, POST SL-1 LAUNCH

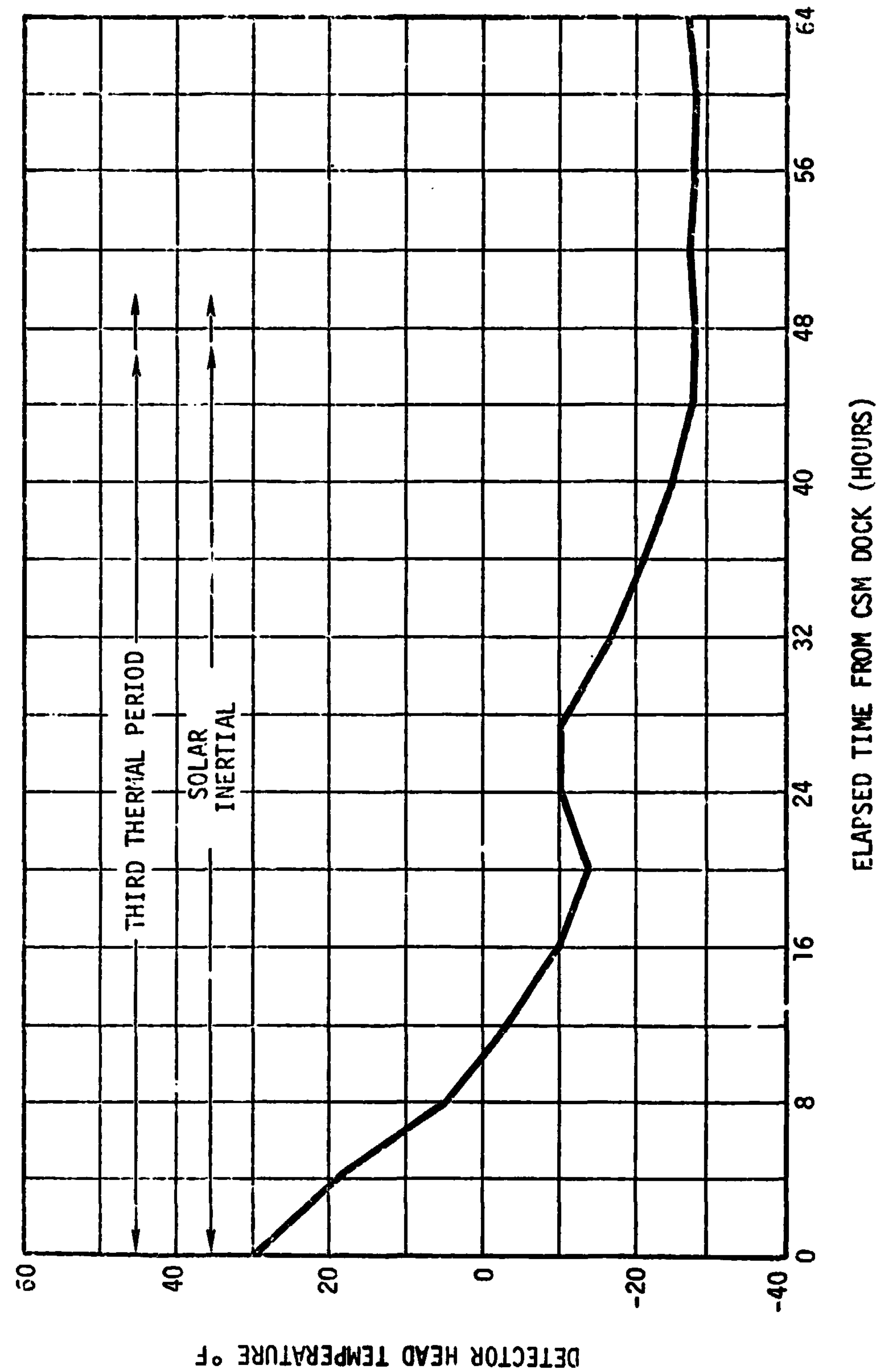


FIGURE IV-38. PROTON SPECTROMETER TEMPERATURE PROFILE, POST SL-2 CSM DOCKING

SECTION V. MATERIALS PROCESSING EXPERIMENTS

A. Materials Processing Facility Experiments

1. M512 - Materials Processing Facility. The facility Technical Manager/Principal Investigator is Mr. P. Gordon Parks, Process Engineering Laboratory, MSFC, Huntsville, Alabama. The Hardware Developer for all facility/experiment hardware was the Process Engineering Laboratory, MSFC, Huntsville, Alabama.

a. Facility Description

(1) Objective. The objective was to provide a basic apparatus and a common spacecraft interface for performance of metallic and non-metallic materials processing experiments, utilizing the advantages of the near-zero-g and vacuum conditions afforded by the Skylab workshop.

(2) Concept. To fulfill this objective, a materials processing facility (MPF) was designed for the Skylab program. Obviously the near-zero-g conditions were readily available; however experiments requiring vacuum conditions had previously been constrained to EVA operations. The M512 facility was designed to allow experiment performance under controlled vacuum conditions inside the Skylab spacecraft.

The facility concept provided the flexibility to perform a series of experiments, investigating various areas of materials processing, utilizing one common piece of hardware--the M512 facility.

Data from the experiments was obtained from analysis of the returned samples and certain returned experiment/facility hardware, motion picture records of the two electron beam experiments and M479, plus comments by the operating crewmen. The returned samples were to be studied in comparison with control samples produced on Earth.

(3) Hardware Description. The facility (see figures V-1 and V-2) included the following major subsystems/assemblies: vacuum work chamber assembly, vacuum subsystem, control and display subsystem, electron beam subsystem, electrical power subsystem, water quench subsystem and equipment storage assembly. The facility was hardmounted on two honeycomb mounting panels that were shock-mounted to the longerons running parallel to the MDA X-axis. The facility was located at position II in the forward MDA area (see figure V-3).

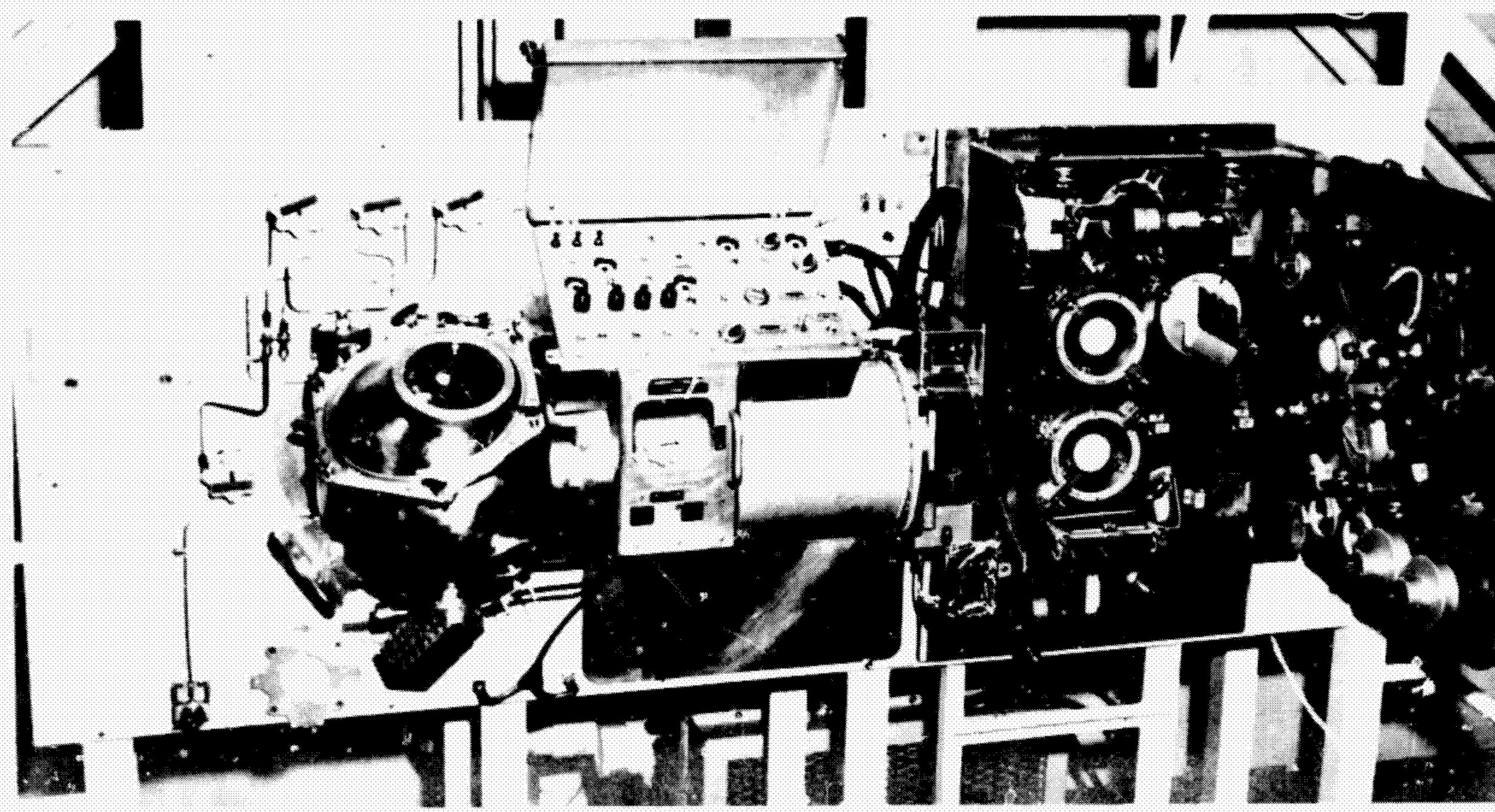


FIGURE V-1. M512 MATERIALS PROCESSING FACILITY

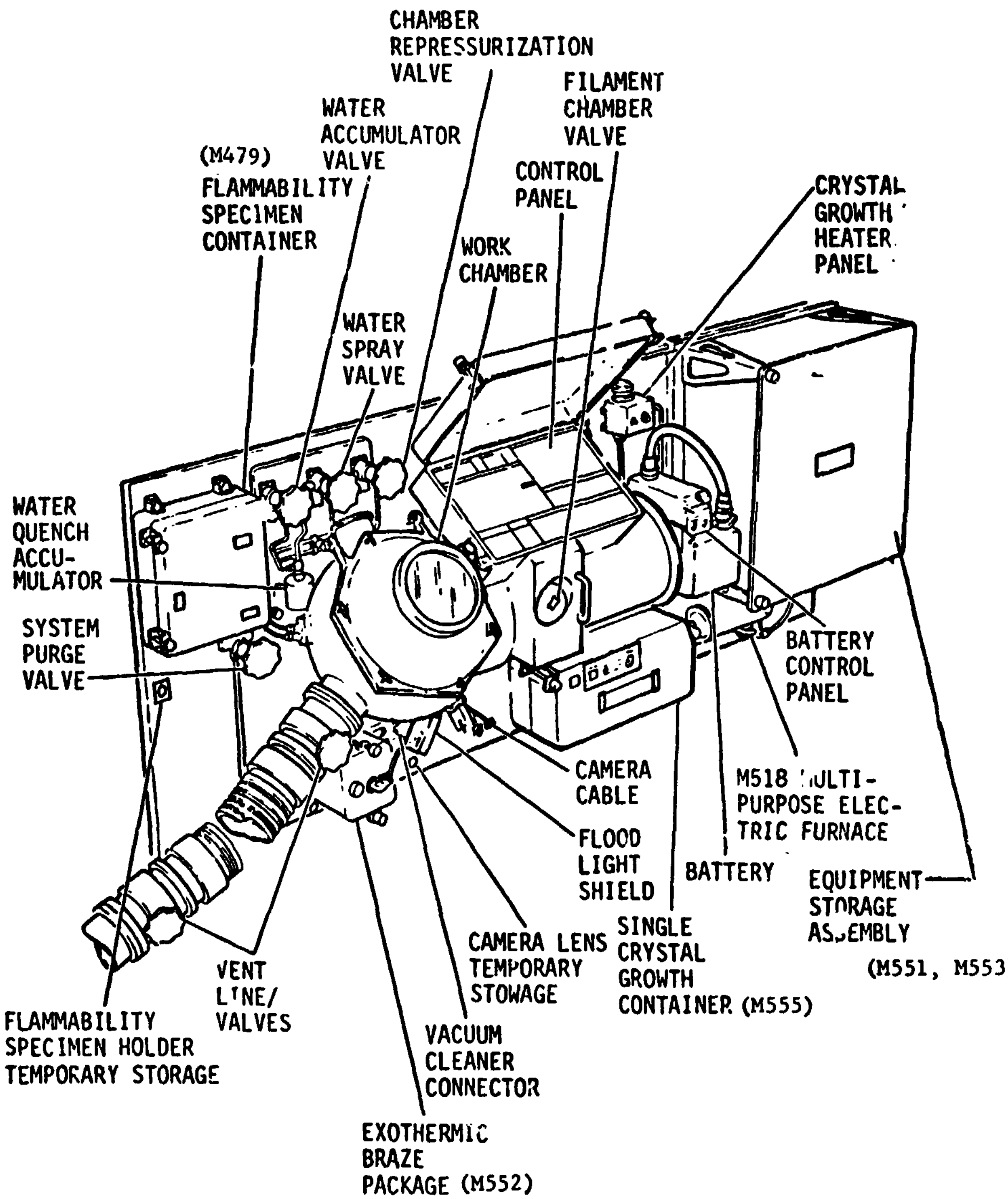


FIGURE V-2. M512 FACILITY LAYOUT

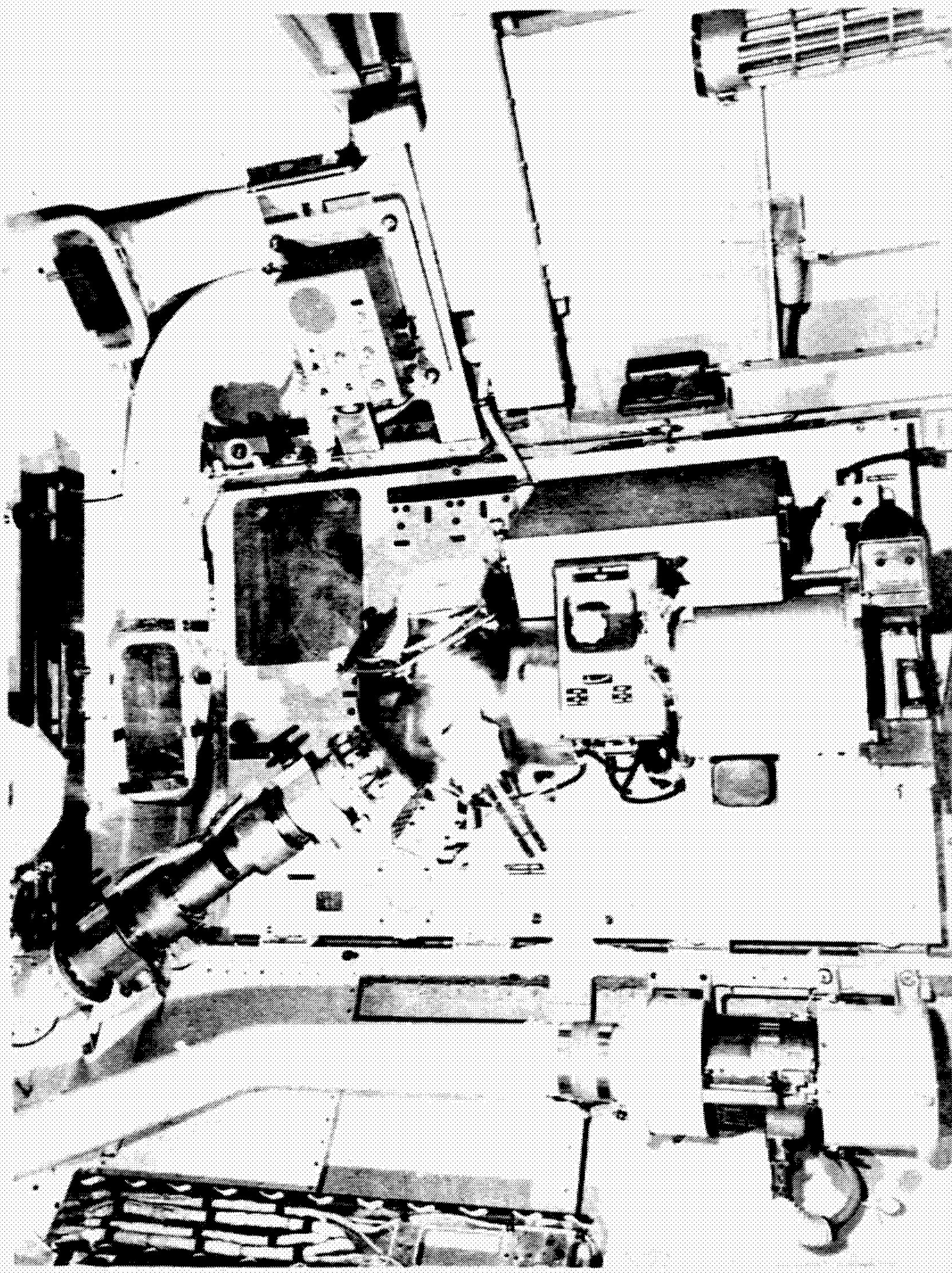


FIGURE V-3. MDA FORWARD AREA WITH M512 INSTALLED

The vacuum work chamber was a 0.4 meter (16-inch) sphere, with a hinged access hatch, in which all experiment operations were performed. The chamber wall contained a cylindrical well (heat sink) that accommodated the small electric furnaces of the M518 and M555 experiments. The heat-sink flange had three mounting holes that interfaced with the mounting bases of experiments M551, M552 and M553 and the M518/M555 clamping ring. Auxiliary provisions included ports for: a floodlight, a 16mm DAC, and crewman observation. Figure V-4 illustrates the work chamber in a "cut away" view. Figure V-5 is a photograph of the empty work chamber and figure V-6 shows a typical experiment (M553) mounted in the chamber. These two photographs were taken from essentially the same angle so that relative locations of the hardware are clearly illustrated. A side-view illustration of the work chamber with experiment M553 installed is shown in figure V-7. This experiment hardware was attached to the heat sink outer flange (as contrasted to the M518 furnace that was inserted into the heat sink cavity). A vacuum cleaner port was provided for cleaning the chamber, and a repressurization line with valve was used to equalize chamber/MDA pressure after each experiment operation.

The vacuum subsystem connected the work chamber to the space environment. The subsystem consisted of a 0.1 meter (4-inch) diameter line with two butterfly poppet valves (see figure V-3).

The control panel (figure V-8) incorporated the controls and displays required for the experiments utilizing the facility. Included were a vacuum gauge and a thermocouple temperature indicator for the work chamber, and voltage and current meters for the electron beam subsystem. The panel controls and displays were grouped into various sections, with each section devoted to a particular facility function or experiment (e.g., electron beam section or flammability section).

The electron beam subsystem was mounted to the chamber enabling the beam to traverse the sphere along a diameter parallel to the hatch closure plane. The electron beam welder operated nominally at 20 kilovolts and 80 milliamperes, and was provided with focusing and deflection coils that could be operated from the control panel. The electron beam gun port is shown in figure V-6.

Electrical power (+28 VDC) for the facility and experiments was supplied by either the M512 battery or the AM power system. A zero-g receptacle in the work chamber provided power for the M512 series experiment, and can be seen to the left of the heat sink cavity in figure V-5. Figures V-6 and V-7 show a typical experiment mechanically and electrically installed in the chamber. The battery power was used for the electron beam operation and the exothermic brazing ignition. The AM power was used for all other experiment operations.

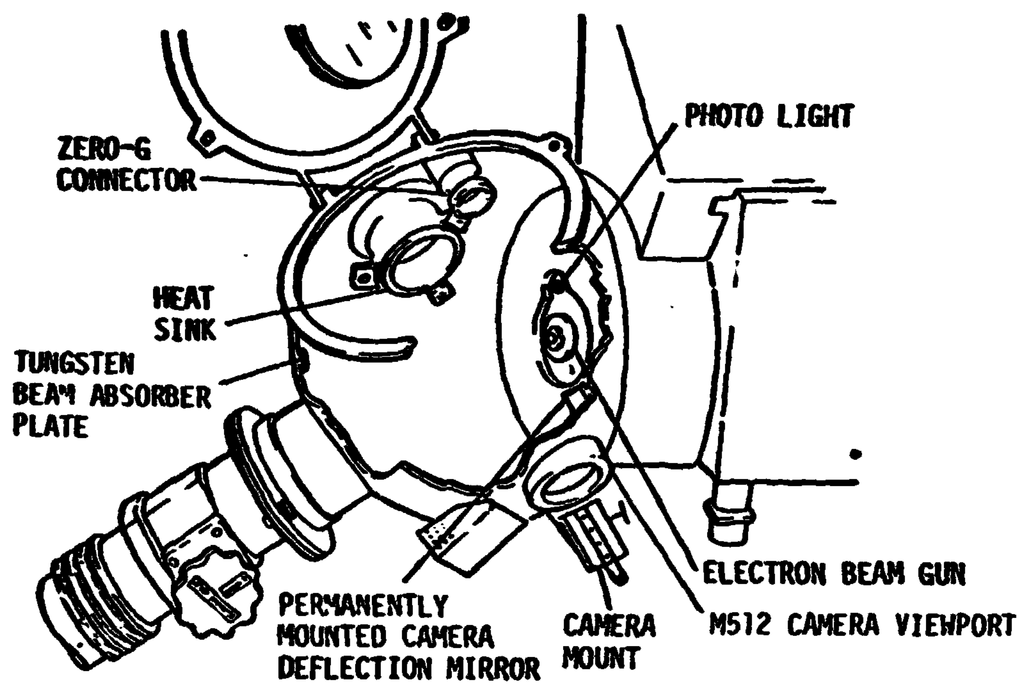


FIGURE V-4. M512 WORK CHAMBER - INTERIOR LAYOUT

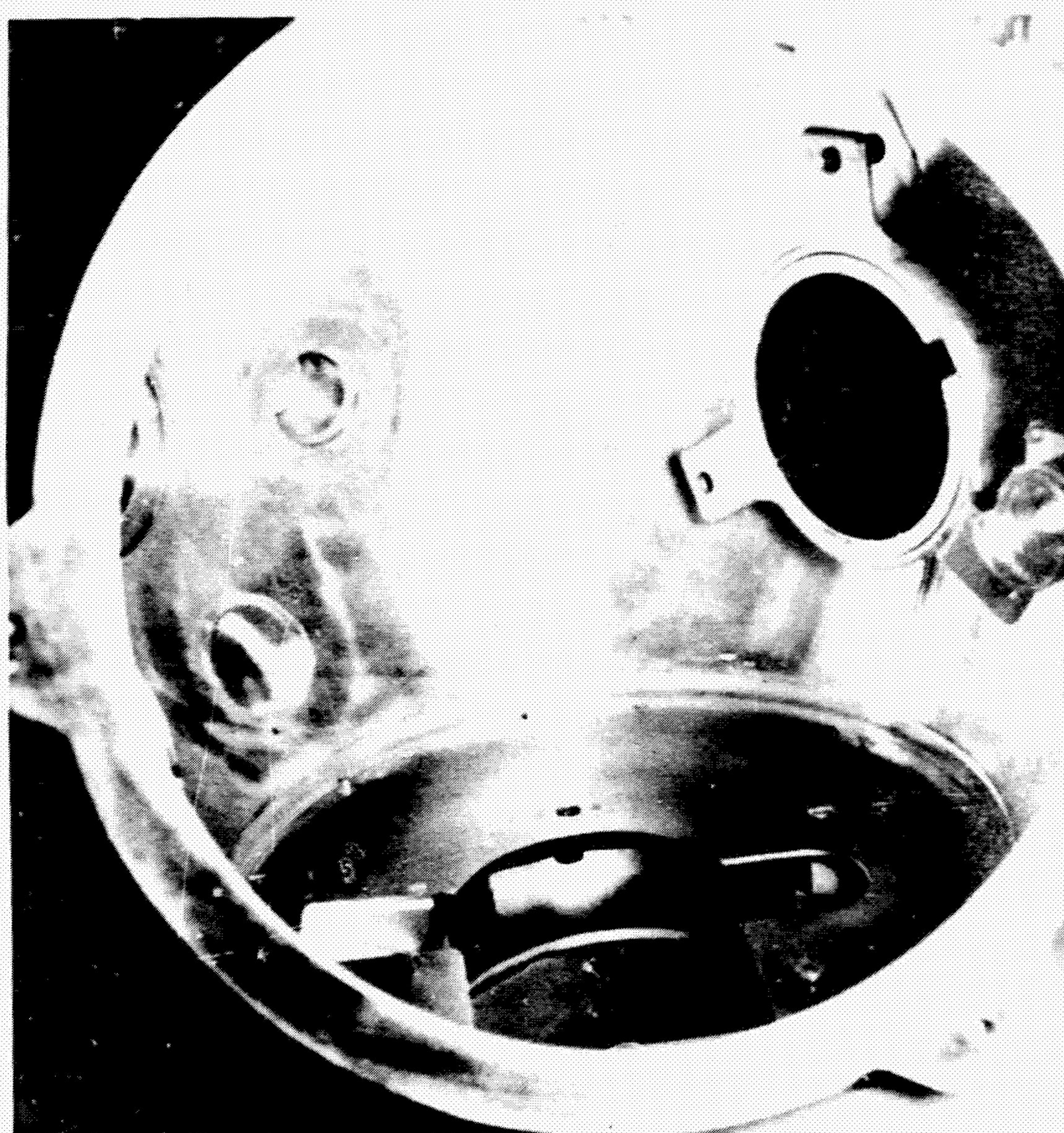


FIGURE V-5. M512 WORK CHAMBER - INTERIOR VIEW

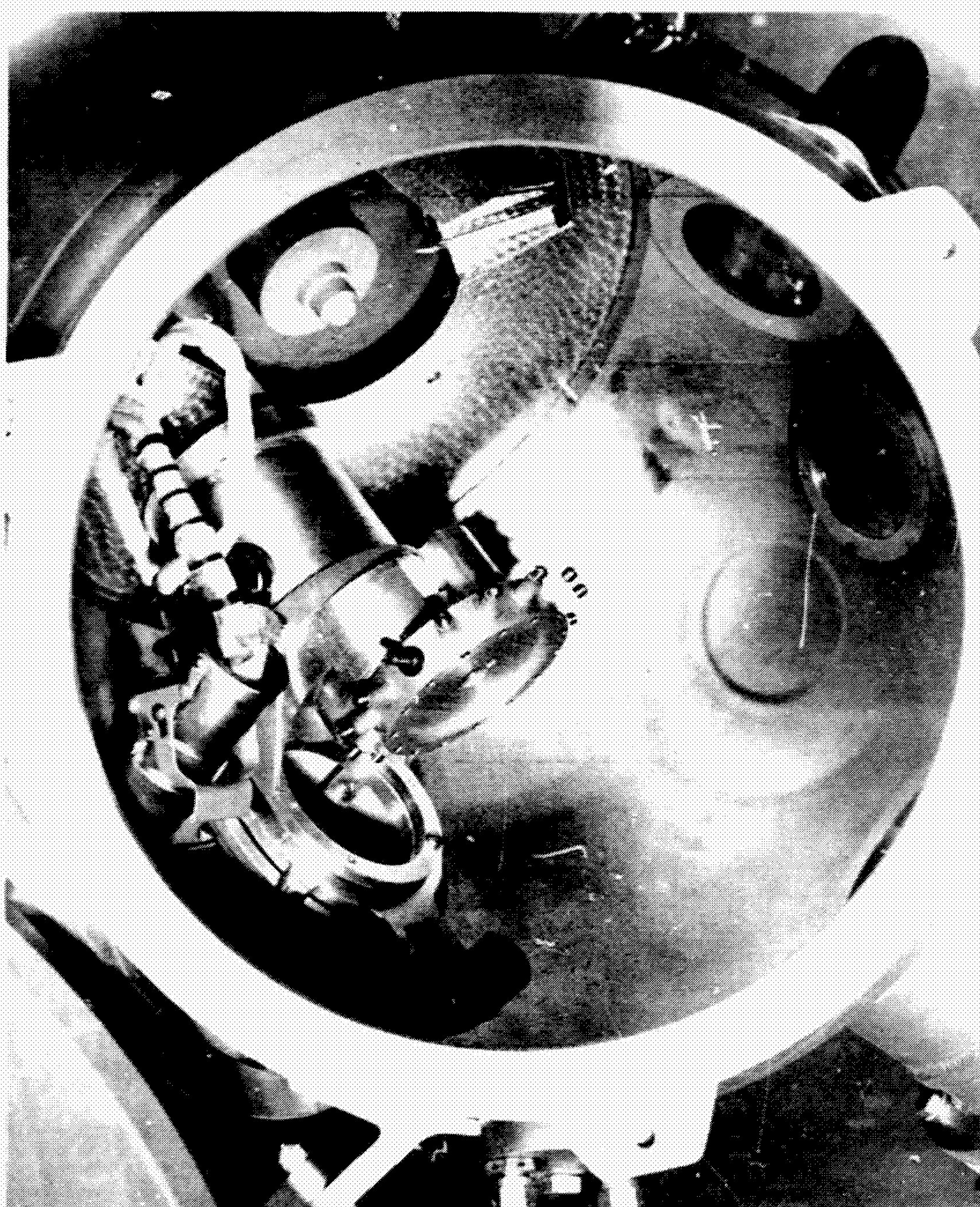


FIGURE V-6. M512 WORK CHAMBER WITH EXPERIMENT INSTALLED

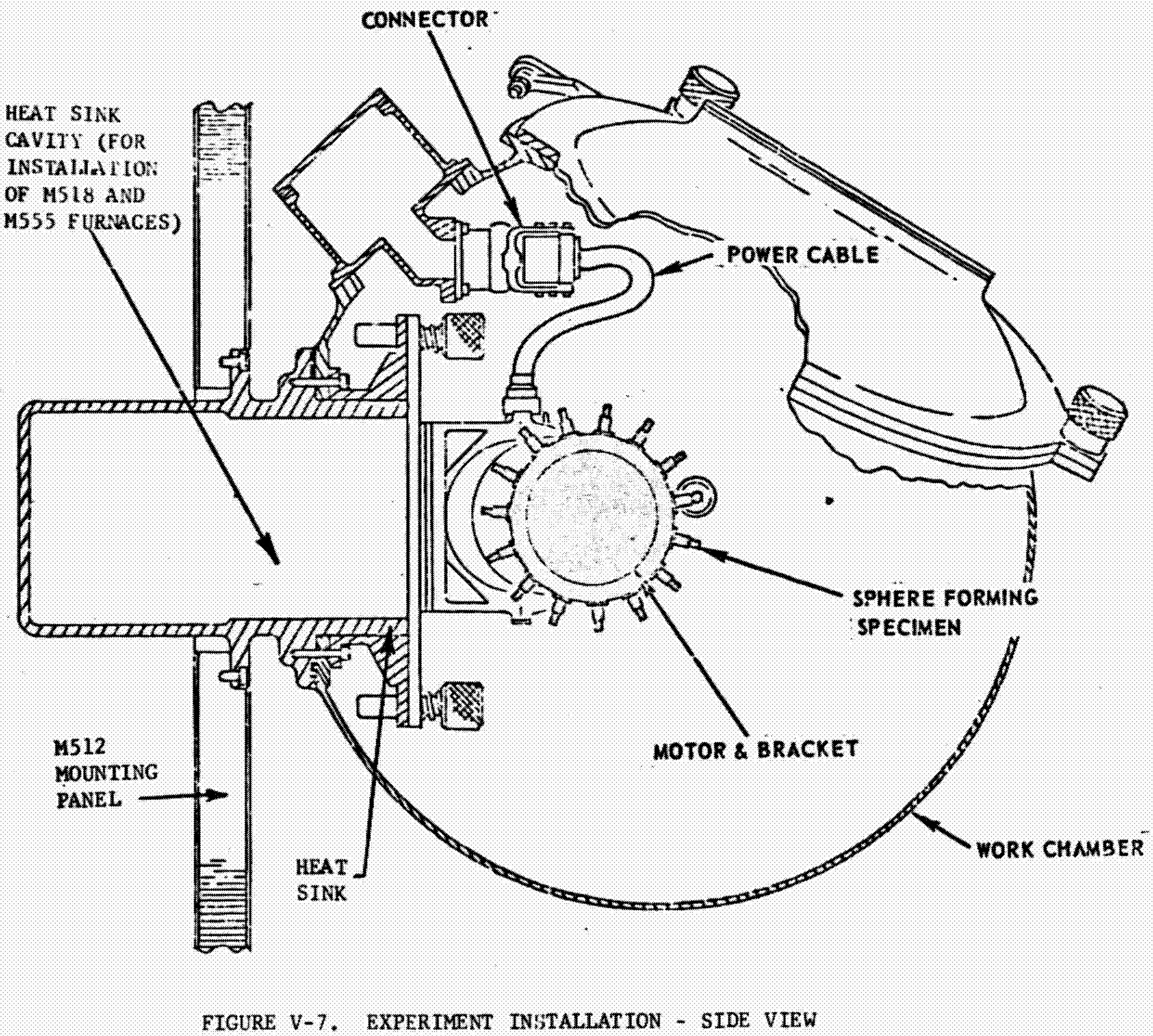


FIGURE V-7. EXPERIMENT INSTALLATION - SIDE VIEW

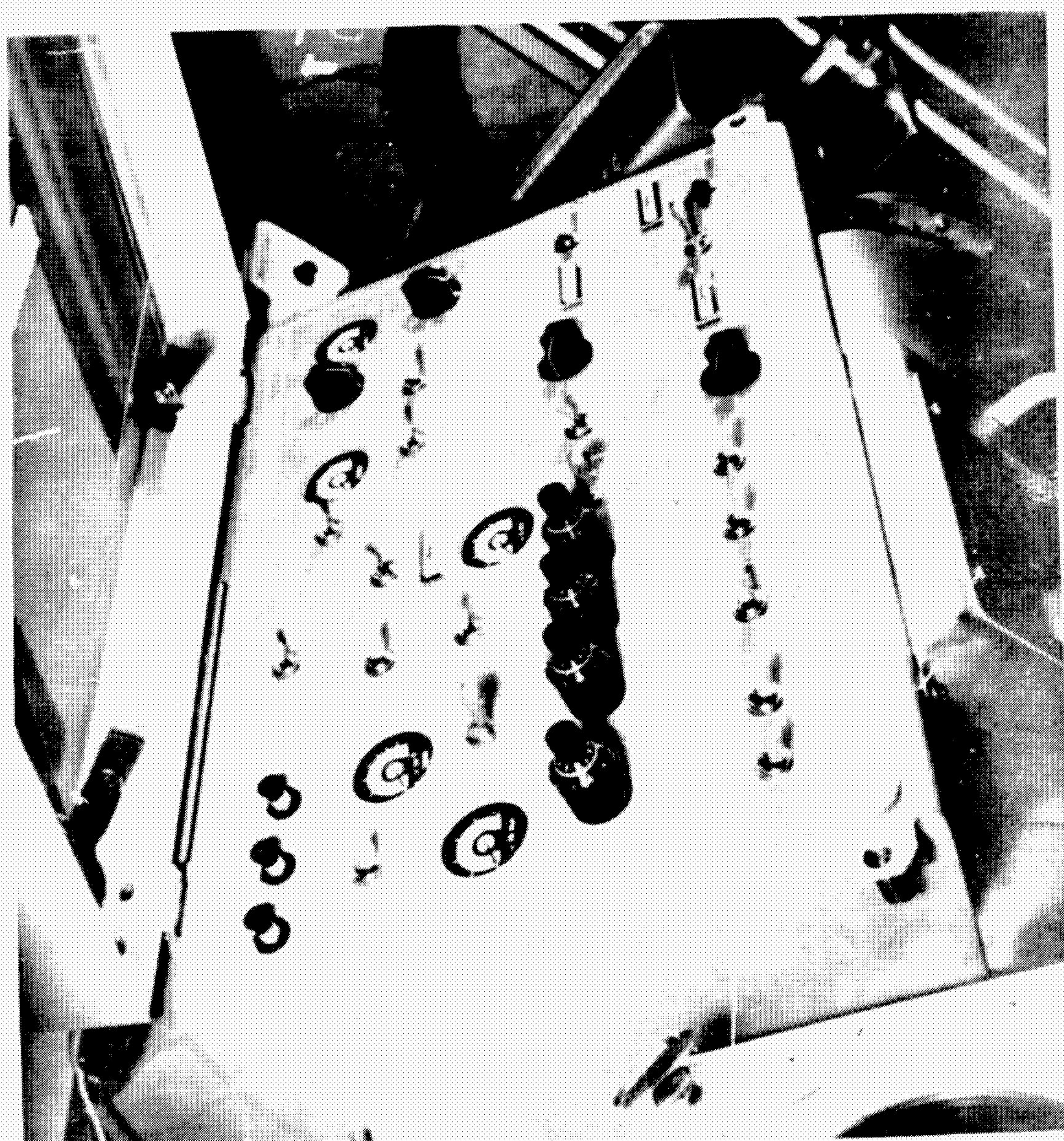


FIGURE V-8. M512 CONTROL PANEL

The water quench subsystem provided the water that sprayed into the chamber during the experiment M479 performance.

Experiment hardware for several materials processing experiments (M479, M555, M552 and the M518 Multipurpose Electric Furnace) were mounted on the facility mounting panels (see figure V-2). Hardware and samples for the remaining experiments (M551 and M553) plus facility hardware items required for experiment operations were launched and stored in the equipment storage assembly (see figure V-9).

b. Facility Operation. One crewman was required for facility and experiment operations. Operation of three experiments (M551, M553 and M479) required continuous crew participation; however, the other experiment's operations were essentially automatic after initial setup. A detailed discussion of each experiment's performance is included in individual experiment sections of this document. Crew procedures for the facility verification and all experiment sequences were included in the MDA Experiment Checklist and Log. The typical operational sequences for an experiment utilizing the facility are summarized in the following paragraphs.

The experiment preparation sequence was essentially the experiment equipment installation and preparing the facility for experiment operation. The procedure involved experiment hardware transfer and installation in the work chamber with the required facility accessory hardware (e.g., mirrors, filters, etc.). During experiment preparation, the DAC was attached to the camera mount on the work chamber exterior face for those experiment operations involving photography. The control and display panel switches were properly configured for the particular experiment operation and the chamber repressurization valve was closed.

The experiment operational sequence included the crew procedures required to operate that particular experiment. The vacuum work chamber was vented to space vacuum and after the desired vacuum level was obtained, the crewman initiated the experiment performance. Following the experiment performance, the chamber was repressurized by closing the two vacuum vent valves and then opening and closing the repressurization valve.

The experiment termination sequence was the removal and stowage of the experiment and facility hardware. The experiment samples and film were stowed for return. The facility controls and valves were returned to pre-operational positions. The work chamber hatch was closed and latched.

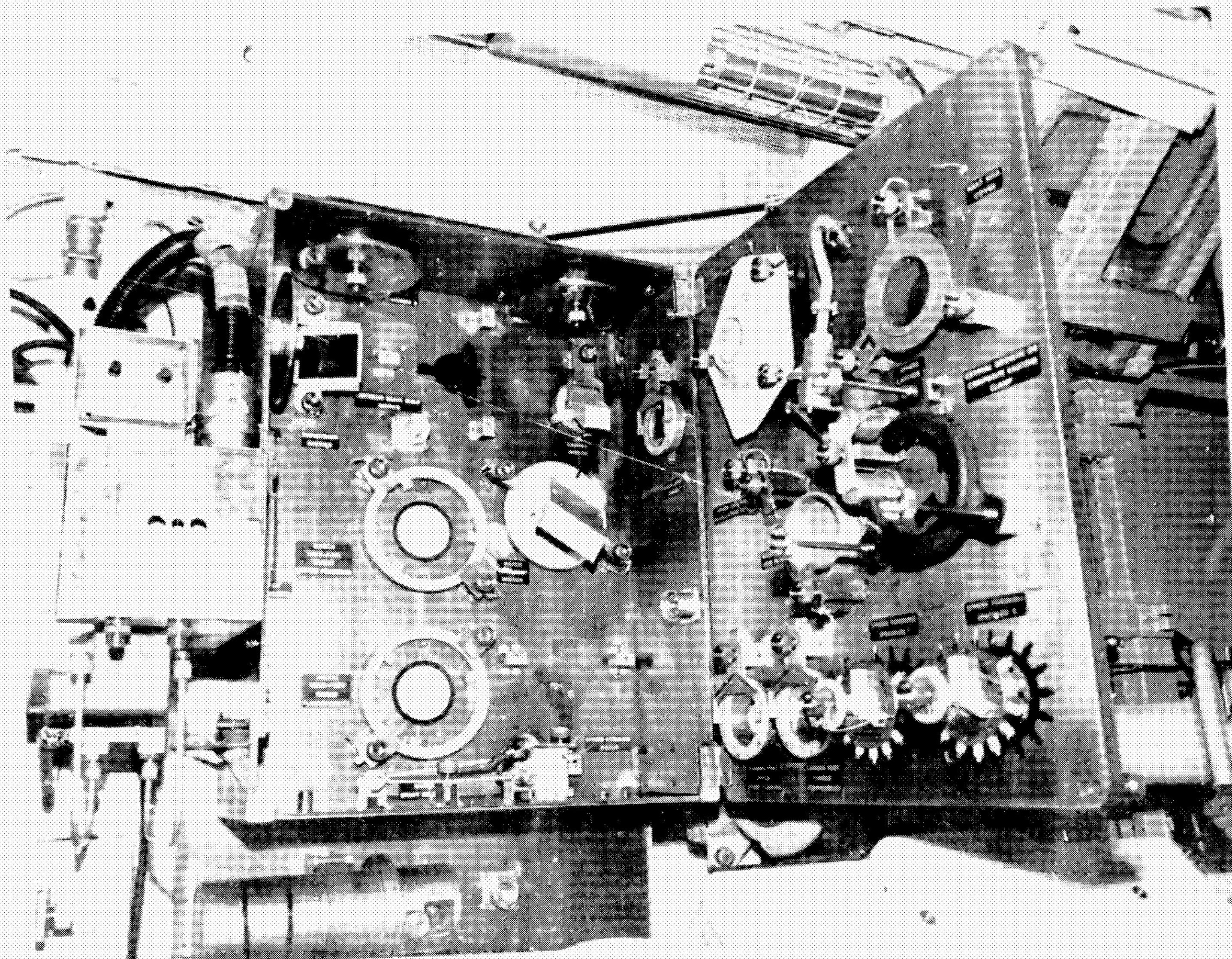


FIGURE V-9. M512 EQUIPMENT STORAGE CONTAINER AND ACCESSORY HARDWARE

(1) Skylab 1/2. The facility verification was performed at 1353 GMT, DOY 162 before any experiment performances. The facility verification was performed once during a mission and was essentially a post-launch inspection of the facility condition and switch configuration.

The first experiment performed was M551 (Metals Melting) on DOYs 163 and 164. Experiment M553 (Sphere Forming) performances were accomplished on DOYs 164 through 166. Experiment M552 (Exothermic Brazing) was performed on DOYs 166 and 167. Following the M552 operation, the M512 battery discharge was initiated on DOY 167. More detailed experiment timeline information is presented in the individual experiment sections.

Experiment M555 (GaAs Crystal Growth) was planned to be performed during SL-1/2. However, the experiment was eventually cancelled from the Skylab Program due to mission-level constraints (see paragraph 6.b.).

(2) Skylab 3. The facility use was not planned during the SL-3 mission. However, late in the SL-3 mission, time became available and the M518 experiments, scheduled for SL-4, were performed on SL-3. The M518 Multipurpose Electric Furnace and its associated experiments utilize the M512 facility. The M518 system is considered a separate facility and is discussed in subsection B.

(3) Skylab 4. Experiment M479 (Zero Gravity Flammability) was performed on DOYs 35, 36 and 38. For details on the M479 operational sequence, refer to paragraph 2. Several M518 experiments were resupplied and performed on SL-4 (see paragraph B.1.b.).

c. Constraints. The experiment constraints were successfully met during the mission.

d. Hardware Performance. This paragraph includes the performance of facility subsystems and facility hardware items that were used during the operations of more than one experiment. As an example, the electron beam subsystem was used for M551 and M553 experiment operations and will be evaluated in the M512 facility section.

(1) SL-1/2 Performance. Experiment operations (M551, M552, M553) during the first mission required the most extensive use of the M512 facility subsystems and hardware during the Skylab Program.

Experiments M551 and M553 operation resulted in the only electron beam subsystem use during the Skylab Program. On SL-1/2, the M512 battery was utilized as a power source rather than the AM power system.

Essentially all the hardware items (except the M479 items) stored in the equipment storage container (see figure V-9) were used at least once during this mission.

The facility performed as designed with two exceptions.

(a) Time to Vacuum. Pre-mission time estimates were basically analytical in nature, since actual time-to-vacuum data had never been obtained during a manned mission. An estimate of thirty minutes to reach the desired pressure level of 1×10^{-4} torr was used to establish premission experiment timelines. During the first chamber evacuation for performance of M551, approximately two and one-half hours were required to obtain this vacuum level. A substantial amount of outgassing was expected during the initial chamber evacuation; however, the increased time may indicate that the space vacuum pumping ability of the immediate Skylab environment was not as efficient as predicted. The situation did not affect the performance of M551 and is not considered a facility anomaly.

At 1500 GMT on DOY 163, the crew stated that they were "not getting any reading on the filament chamber pressure meter", but the work chamber pressure gauge showed a zero reading. The work chamber pressure gauge was a gauge registering from 15 to zero psia pressure, and the crew later related that this gauge went to zero immediately after the 4-inch vacuum vent valves were opened. The filament chamber pressure gauge (vacuum gauge) registered from 5×10^{-3} torr to 1×10^{-5} torr, utilizing a sensor located in the electron beam filament chamber, while the work chamber pressure sensor was located in the work chamber itself. The vacuum gauge sensor was located in that position because the vacuum level was more critical in the filament chamber for the electron beam gun activation/operation than to experiment operations in the work chamber.

The filament chamber was connected to the work chamber by a three-quarter-inch diameter line with a valve (filament chamber vent valve). As a result of this configuration, a time lag was expected between a zero pressure reading on the work chamber pressure gauge and the activation of the filament chamber pressure gauge. This proved to be the case in this situation because at 1744 GMT on DOY 163, the crew stated that the filament chamber pressure gauge "was just very slow coming on line", but that the proper pressure level was obtained and M551 operations had begun.

Each of the two subsequent pump-downs for the remaining M551 samples required approximately one hour. The first M553 specimen wheel was installed in the work chamber prior to the DOY 165 sleep period. The work chamber was evacuated during the sleep period

to establish a good vacuum for the first M553 operation early in the crew workday. As a safety precaution, the vent valve configuration during sleep periods was one valve in the fully OPEN position and the other valve in the VENT position (90% closed). On DOY 165, the CDR stated that the vacuum gauge reading was 1 x 10^{-5} torr, which was the best vacuum obtained in the chamber during the Skylab missions.

During the M553 operations, the vacuum problem continued, with extra evacuations in excess of one hour required after melting only one or two M553 samples. Crew checklists and timelines had been formulated with the assumption that the pressure increase that occurred during sample melting would be easily removed between sample operations. However, it appeared that the pressure continued to increase to a point where the crewman had to interrupt operations, after only a few samples, to allow the chamber vacuum to be reestablished before continuation. These longer and more frequent delays to reestablish the desired vacuum impacted the mission timelines, and ultimately led to an early termination of the second M553 specimen wheel to assure sufficient time for the performance of M552.

(b) Electron Beam Gun Operation. The M512 electron beam gun failed to turn off (see paragrach 1.g. Anomalies) when the ready/reset switch was operated to terminate operations after the third and last M551 sample (DOY 164). This anomaly also occurred intermittently during the M553 performances. The situation was continuously monitored, malfunction isolation analysis performed, and several work-around procedures formulated. These procedures enabled a successful completion of all M553 samples, except those not completed as a result of the time constraints just discussed.

(2) SL-3 Performance. The M518 Multipurpose Electric Furnace System utilized the M512 facility during this mission. The M518 system is evaluated in subsection B; however, the M512 facility involvement in the M518 operations will be discussed at this time.

The M518 system operated essentially independently of the M512 facility after installation, with the only requirements on the facility being establishment of a proper vacuum and activation of the facility vacuum gauge for pressure verification.

There was no requirement for the crew to record the time-to-vacuum for the M512 or M518 experiments. However, to obtain a second data point, the crew was asked to record the time-to-vacuum for experiment M562 (the second experiment in the M518 series). The crew reported that only nine minutes were required to reach 5 x 10^{-4}. torr as compared to a premission estimate of approximately thirty minutes. It should be noted that the greater amount of hardware outgassing would have occurred during the initial chamber evacuation

(after the installation of the M518 furnace) rather than between experiment operations (when this data point was taken), but the initial evacuation times were not recorded.

The vacuum gauge continued to perform properly during the Skylab 3 mission.

(3) SL-4 Performance. The M512 facility support of M518 operations was the same on this mission as on Skylab 3 and all support requirements were met. It is interesting to note that when time-to-vacuum was recorded on this mission, 45 to 90 minutes was required.

The last experiment operation performed was M479 Zero-Gravity Flammability and the facility performed satisfactorily during these operations. The problems associated with the water quench nozzle are discussed with the M479 experiment in paragraph 2.

e. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

f. Return Data

(1) Skylab 1/2. All physical hardware, relative to the M512 facility, returned on this mission was associated with individual experiments. However, the crew evaluation of the facility design was voice-recorded during the mission and was further discussed during the SL-1/2 Crew Debreifing held at JSC on July 6, 1973. The M512 facility was shown during two television episodes: TV-24 on DOY 174 during the M551 operations and TV-26, on DOY 178 during the MDA crew "tour".

(2) Skylab 3. No M512 hardware was planned for return on SL-3; however, as a result of crew comments made during the SL-2 crew debriefings, three M512 items were approved for return on SL-3. The SL-2 crew had discussed the metal deposition or plating that occurred on hardware items installed in the chamber during performance of experiments M551 and M553. The following M512 accessory items were returned for evaluation:

Protective cover assembly - P/N 95M11637-1

Camera port shield - P/N 95M10411-1

Viewport cover assembly - P/N 95M10475-1

(3) Skylab 4. All physical data returned on SL-4 pertained to experiment M479 (see paragraph 2.f.).

g. Anomalies. The M512 electron beam anomaly was first reported at 0038 GMT on DOY 164 after the "dwell" sequence (electron beam fixed on one point) on the third M551 sample, when the CDR made the following voice transmission (with some terminology corrections):

"On the third plate, when I got to the cross and was doing the pooling (dwell), at the end of the amount of time for the electron beam gun to be on, I hit the ready/reset switch to turn it off and it would not turn off. So I reached up and turned off the fil/beam power switch. This shut the beam off, but I could hear something clicking away back by the battery, the X5KV meter was still on for some reason. The only way I could get this shut off was to pull the main batt cb. Went through malfunction procedures - zero. Plugged main batt cb back on and sure enough the 5KVA was still on. Turn on the fil/beam power switch and that turned the X5KV meter off. About that time, the electron beam came on by itself; so I decided a relay was sticking on something. I pulled the fil bat cb this time and reset it, and that action reset everything that was wrong in there. I finished the specimen."

Malfunction isolation to one component could not be completed with the data available from this voice communication; however, after analysis and testing on the M512 Qual Unit at MSFC, the situation was reduced to four candidate failure modes.

A work-around procedure and a malfunction isolation procedure were developed at MSFC and transmitted to JSC for uplink to crew after their sleep period (DOY 164). Assuming that the third M551 specimen remained in the chamber (per flight plan), it was concluded that the electron beam gun condition could be determined on DOY 164 for M551 termination and stowage. The following recommendations were made concerning implementation of the procedures:

Perform the procedures on the M551 specimen still in the chamber.

If the electron beam gun operates normally, proceed with M553 operations per crew checklist.

If the electron beam gun malfunctions, proceed with malfunction isolation procedure. It should be performed to obtain the information required to support a proper decision on further operations of the M553 and M552 experiments.

However, when the crew was contacted, the CDR reported that he had already removed the M551 sample and installed the first M553 sample. The procedures were revised for implementation during the M553 operation.

The CDR stated that he had already begun the M553 alignment. The electron beam gun operated normally and the crew was informed that M553 operations should be continued using the normal crew checklist. It was concluded that the probable cause was a momentarily sticking K3 relay.

The electron beam gun operated normally for the first five M553 samples on specimen wheel 1. The malfunction reoccurred at this time and malfunction procedures were again formulated. The CDR continued to perform the M553 operations, completing the first specimen wheel and seven of the 14 samples on the second wheel. The malfunction occurred intermittently and the CDR used alternate procedures to shut off the beam at these times. The M553 operations were terminated at this point, due to the increased time required per sample operation (see paragraphs 1.d and 5.b.).

The answers to questions posed by experiment development personnel at the Skylab 1/2 Crew Debriefing (July 6, 1973) and the real-time information obtained during the mission were the basis for a malfunction analysis report* on this anomaly. The malfunction analysis concludes that the anomaly was caused by an intermittent fast-cut-off circuit in combination with a sticking K3 relay.

2. Experiment M479 - Zero Gravity Flammability. The Principal Investigator is Mr. J. Howard Kimzey of the Lyndon B. Johnson Space Center, Houston, Texas. The experiment was developed by the Process Engineering Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama.

a. Experiment Description. The M512 facility presented the first hardware on a space mission capable of safely performing flammability tests.

(1) Objective. The experiment objective was to ignite various materials in a 5 psia spacecraft atmosphere (nominally 70% oxygen - 30% nitrogen) under zero-g conditions to observe the following:

Extent of surface propagation flash-over to adjacent materials,

Rates of surface and bulk flame propagation under zero convection,

Extinguishment by vacuum or water spray and self-extinguishment.

(2) Concept. Material samples were to be electrically ignited in the pressurized chamber (using cabin atmosphere). Individual flammability test duration would be from a minimum of three seconds to a maximum of over a minute.

*Refer to Reference Section for Test Report.

The flammability process was to be recorded on 16mm film in the visible (color) and infrared regions. Additional data would be obtained from the recorded crewman's voice comments while performing the experiment. The crewman would be invaluable in observing several test aspects that could be missed by photography, such as: drift rates of detached fuel specimens; sublimation products, overall energy profiles; environmental changes in the chamber, and water-spray patterns. A detailed crew observation log form for each test was to be included in the MDA Experiment Crew Procedures and Log.

(3) Hardware Description. The M479 hardware consisted of the following:

Experiment Hardware	Function
Flammability sample	A typical flammability sample is shown in figure V-10. The sample material was supported by a metallic frame and the sample identified by a number tag (Number 7 in figure V-10). The sample was ignited by an electrically heated filament which obtained power through the connector shown on the right side of the figure. Power for sample ignition was +28 VDC from AM Bus 1, through the M512 control panel flammability section. Six different substances were used as sample materials: aluminized Mylar film 6.7 cm by 9.2 cm (2 5/8 in. by 3 5/8 in.), nylon sheet, 2.5 cm by 2.5 cm (1 in. by 1 in.), neoprene-coated nylon fabric, 6.7 cm by 9.2 cm (2 5/8 in. by 3 5/8 in.), polyurethane foam, 0.6 cm by 0.6 cm by 5 cm (0.25 in. by 0.25 in. by 2 in.), bleached cellulose paper 6.7 cm by 9.2 cm (2 5/8 in. by 3 5/8 in.), and teflon fabric, 6.7 cm by 9.2 cm (2 5/8 in. by 3 5/8 in.).

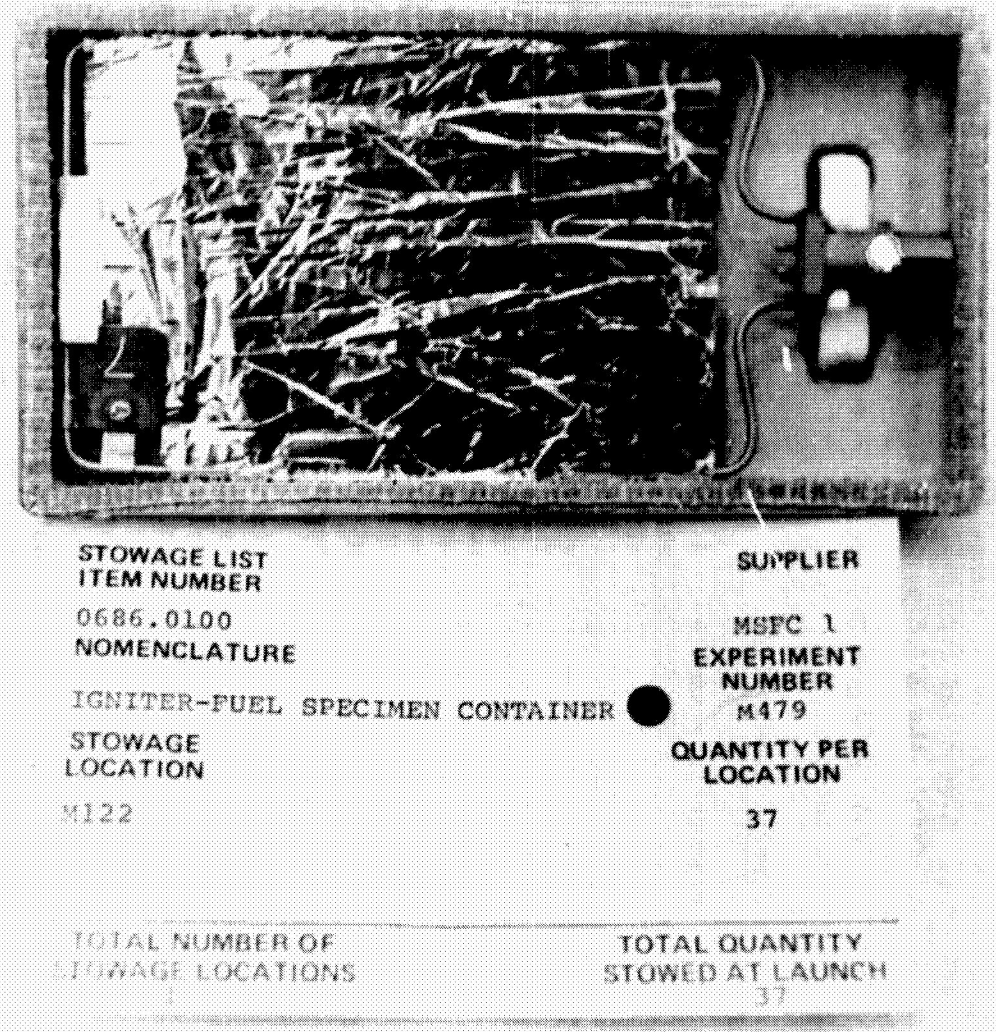


FIGURE V-10. M479 SAMPLE IN CONTAINER

Experiment Hardware	Function
Specimen holder	The flammability specimen holder (figures V-9 and V-11) was the mechanical and lectrical interface between the flammability sample and the zero-g connector in the work chamber. The holder configuration positioned the specimen in the approximate center of the chamber, in the 16mm DAC FOV.
Flammability specimen container	The 37 flammability samples were stored in separate specimen boxes (see figure V-10) and these boxes stored in the flammability specimen container in the upper left corner of the M512 mounting panel (see figure V-2).
Water spray nozzle	The water spray nozzle was designed to attach to the work chamber interior and spray two ounces of water on each sample during six sample operations. The water was obtained from the OWS water system through the 50-foot water umbilical.

b. Experiment Operation. A typical experiment operation involved the installation of a sample on the sample holder and this assembly installed onto the zero-g connector in the work chamber. The work chamber had been filled with cabin air and the chamber repressurization valve was closed. The sample identification (ID) number was recorded on the film by activation of the sample ID switch. Sample ignition occurred when the data start switch was activated and the camera automatically ran for the time period preset on the control panel.

Sample extinguishment was accomplished by one of three methods: self-extinguishment or sample burnout by itself; vacuum quench or opening of the vent line to space vacuum; or water quench (i.e., spraying) of the sample with two ounces of water. A photograph of the sample was taken after the burnout or extinguishment was completed.

The M479 operations began on Mission SL-4, DOY 35 at 1340 GMT. All thirty-seven operations were scheduled during one crew day (DOYs 35 and 36); however, due to other priority operations, the crew was able to finish only samples 1 through 30 during this time.

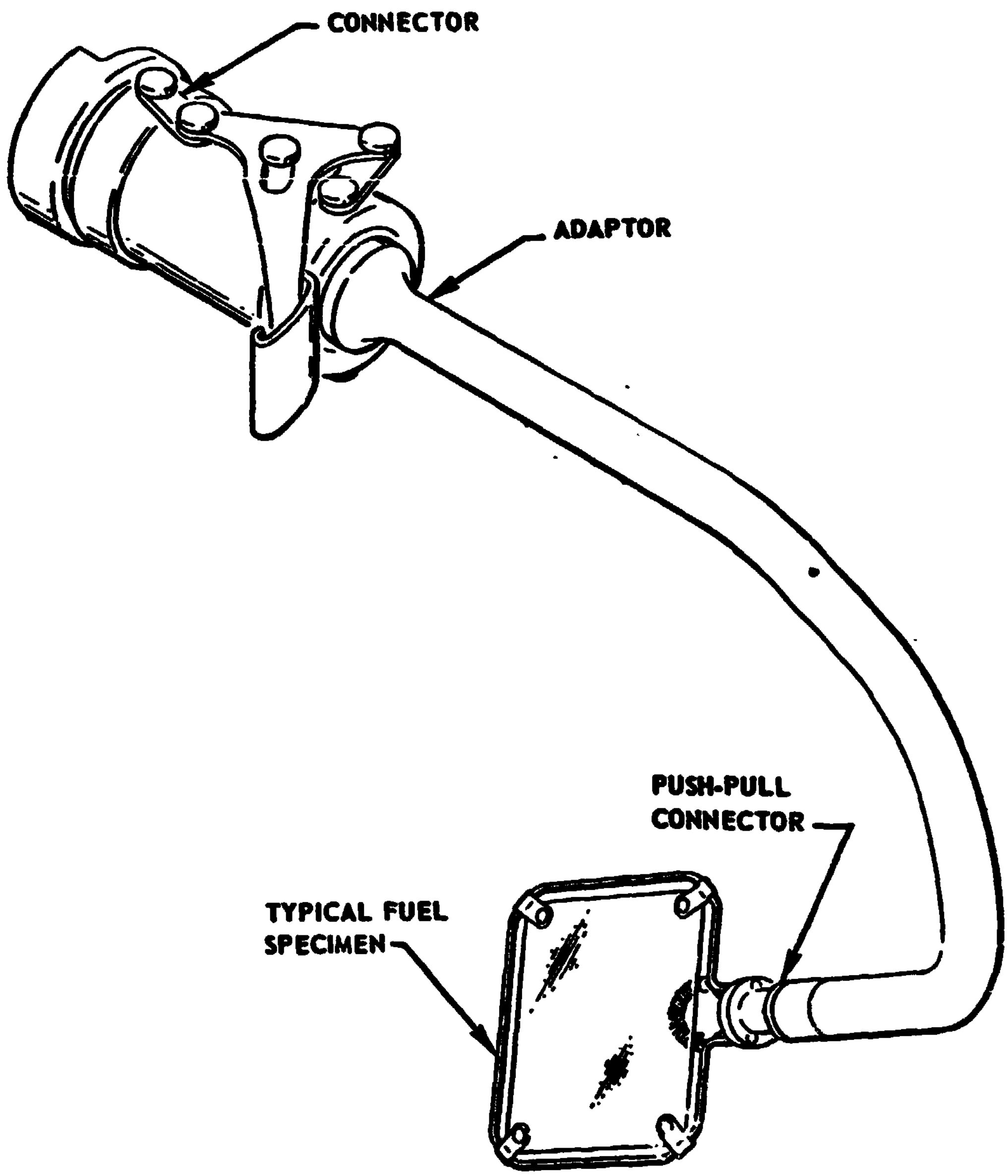


FIGURE V-11. M479 FLAMMABILITY SPECIMEN HOLDER WITH SAMPLE INSTALLED (OPERATIONAL CONFIGURATION)

Samples 1 through 12 consisted of two samples of each material that were allowed to burn undisturbed to test for self-extinguishment. Samples 13 through 18 consisted of one sample of each material that tested the vacuum mode of extinguishment. Samples 19 through 24 tested the water quench extinguishment mode and the effects of water impingement on the sample. It was during the sample 21 operations that the CDR made the following report:

> "Okay, I'm trying to do it right now. I've done samples 19 and 20, and the water-quench system is not working properly...the lower nozzle appears to be completely plugged. And I just don't have time to mess with it to try to unplug it. The upper nozzle just sends out a dribble rather than a nice spray. So what I've done is I've gone back and completely reserviced the system again, and we'll try it over again."

That report was made at 0119 GMT, DOY 36, and was the last scheduled conversation with the crew that day.

It was concluded from data given that air may have been present in the water system or umbilical and reservicing should correct this situation. No malfunction analysis was performed since there was no crew contact after this report was made.

However, the recorded tapes received the following morning related that the CDR continued to experience this problem with the water system. The CDR reported that he finished water-quench samples 19 through 24 and samples 25 through 30 before retiring at approximately 0300 GMT, DOY 36. Samples 25 through 30 were only partially supported by the mounts to observe the paths and rates of float as the sample material burned away from the specimen mount.

There were no plans to complete testing the remaining seven samples, however on DOY 38, the CDR finished testing the last samples on his own time. These samples (samples 31 through 37) tested "flash-over" between two sample material strips that were separated by gaps of various dimensions; 0.3 cm, 0.6 cm, and 1.3 cm (1/8 in., 1/4 in., and 1/2 in.).

The following list summarizes the sample operation times:

Sample 1 - 1340 GMT, DOY 35
2 - 1409 GMT, DOY 35
3 - 1447 GMT, DOY 35
4 - 1502 GMT, DOY 35
5 - 1516 GMT, DOY 35
6 - 1527 GMT, DOY 35
7 - 1545 GMT, DOY 35
8 - 1552 GMT, DOY 35
9 - 1600 GMT, DOY 35

Sample 10 - 1927 GMT, DOY 35
11 - 1942 GMT, DOY 35
12 - 1952 GMT, DOY 35
13 - 2021 GMT, DOY 35
14 - 2028 GMT, DOY 35
15 - 2035 GMT, DOY 35
16 - 2051 GMT, DOY 35
17 - 2117 GMT, DOY 35
18 - 2126 GMT, DOY 35
19 - 0055 GMT, DOY 36
20 - 0114 GMT, DOY 36
21 - 0134 GMT, DOY 36
22 - 0142 GMT, DOY 36
23 - 0155 GMT, DOY 36
24 - 0214 GMT, DOY 36
25 - 0230 GMT, DOY 36
26 - 0236 GMT, DOY 36
27 - 0240 GMT, DOY 36
28 - 0258 GMT, DOY 36
29 - 0301 GMT, DOY 36
30 - 0306 GMT, DOY 36
31 - 0258 GMT, DOY 38
32 - 0303 GMT, DOY 38
33 - 0306 GMT, DOY 38
34 - 3010 GMT, DOY 38
35 - 0314 GMT, DOY 38
36 - 0319 GMT, DOY 38
37 - 0323 GMT, DOY 38

c. Constraints. The experiment constraints were successfully met during the mission.

d. Hardware Performance. All M479 hardware performed as designed with the exception of the water quench system. There was no opportunity to perform any water-quench malfunction isolation. However, the following morning at JSC, the problem was discussed with the water management personnel. They stated that the records indicated that the water tank to which the umbilical was attached had not been pressurized (with N_2) since the SL-1/2 mission. The SL-4 crew procedures did not require a check of this system because premission planning was based upon that tank being pressurized. Therefore, it was concluded that insufficient tank pressure caused the water-quench problem.

The CDR was able to work around the problem to some extent by utilizing the accumulator hand pump located on the water-quench accumulator top (see figure V-2). This accumulator pump was designed to assure that the accumulator contained sufficient water

prior to the first water-quench operation. The CDR's hand pump use provided sufficient water pressure to obtain some water-quench data on at least two samples. This problem was not considered a hardware anomaly.

e. Interfaces. The experiment interfaces performed satisfactorily during the mission.

f. Return Data. The following M479 data was returned on SL-4 for evaluation:

Four rolls of 16mm film data (one IR, three visible-color).

The remains of fuel specimens 2 (nylon), 8 (nylon), 11 (paper), and 26 (nylon).

TV-66 coverage of sample 2 before and after ignition and samples 16 and 17 test sequences.

Extensive crew observations (voice-recorded during the mission) and the crew comments made at the SL-4 Crew Debriefing held at JSC on March 4, 1974.

g. Anomalies. There were no anomalies associated with the M479 hardware.

3. M551 - Metals Melting. The Principal Investigator is Mr. Richard M. Poorman, Astronautics Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. The experiment was developed by the Process Engineering Laboratory, MSFC, Huntsville, Alabama.

a. Experiment Description

(1) Objective. The objectives were to study the behavior of molten metals in free fall at low acceleration levels, to characterize the structures formed in metals melted and rapidly solidified in free fall, and to test the possibility of joining metals by electron beam welding in space.

(2) Concept. The concept was to heat metal to its melting point and then allow the molten metal to resolidify under zero-g conditions. Three metals (2219 aluminum alloy, type 304 stainless steel and pure tantalum) were to be melted.

(3) Hardware Description. The M551 Experiment hardware consisted of the following:

(a) Samples. The M551 samples (see figures V-9 and V-12) consisted of three metal discs - stainless steel, aluminum, and tantalum. The 2219 aluminum alloy and type 304 stainless steel were selected because they are common structural materials and represent alloys with metallurgy and metallographic characteristics that have been extensively studied. Tantalum was used because it is a pure metal and its solidification behavior would differ substantially from that of the multiphase alloy 2219 aluminum and 304 stainless steel. The cross-sectional thickness at the radius of beam impingement varied to accommodate different operational aspects; i.e., cutting, complete penetration, partial penetration and dwell. The stainless steel and aluminum samples were 16.5 cm (6.5 in.) diameter discs, graduated in thickness from 0.06 cm (0.025 in.) to 0.6 cm (0.25 in.). The tantalum sample was a 16.5 cm (6.5 in.) diameter disc with a graduated thickness from 0.03 cm (0.01 in.) to 0.15 cm (0.06 in.).

(b) Drive assembly. The M551 drive assembly consisting of a tripod mounting base and an electric drive motor, served several major functions during the experiment operation. Figure V-12 illustrates the drive assembly with a sample disc attached to the motor shaft and figure V-9 shows the drive assembly stowage location. The assembly was attached to the heat sink outer flange with three Calfax fasteners, thereby interfacing with the chamber wall. The sample disc clamped to the drive assembly and, when the assembly was placed in the chamber, the sample disc position was such that the tungsten target was approximately on the electron beam axis. The drive assembly included a 28 VDC motor and gear-type speed reducer to rotate the sample disc at a linear rate of 89 cm per minute (35 inches per minute). The motor received power from the M512 battery through the zero-g connector inside the work chamber and was controlled by a three-position switch on the control panel.

(c) Deflection mirror. The deflection mirror (also called the view mirror assembly) is shown in figures V-9 and V-13 and was installed inside the work chamber with two Calfax fasteners. The mirror, used with the hatch viewport mirror (item (d)), enabled the crewman to view the experiment operations through the hatch viewport. The image presented by this mirror system allowed the crewman to see the electron beam strike the sample and to adjust the beam alignment and focus as necessary.

(d) Hatch viewport mirror. The hatch viewport mirror was placed on the interior side of the hatch viewport.

(e) Camera mirror. The camera mirror (see figure V-9) was attached to the chamber interior at the camera viewport to allow the camera to view the experiment operations.

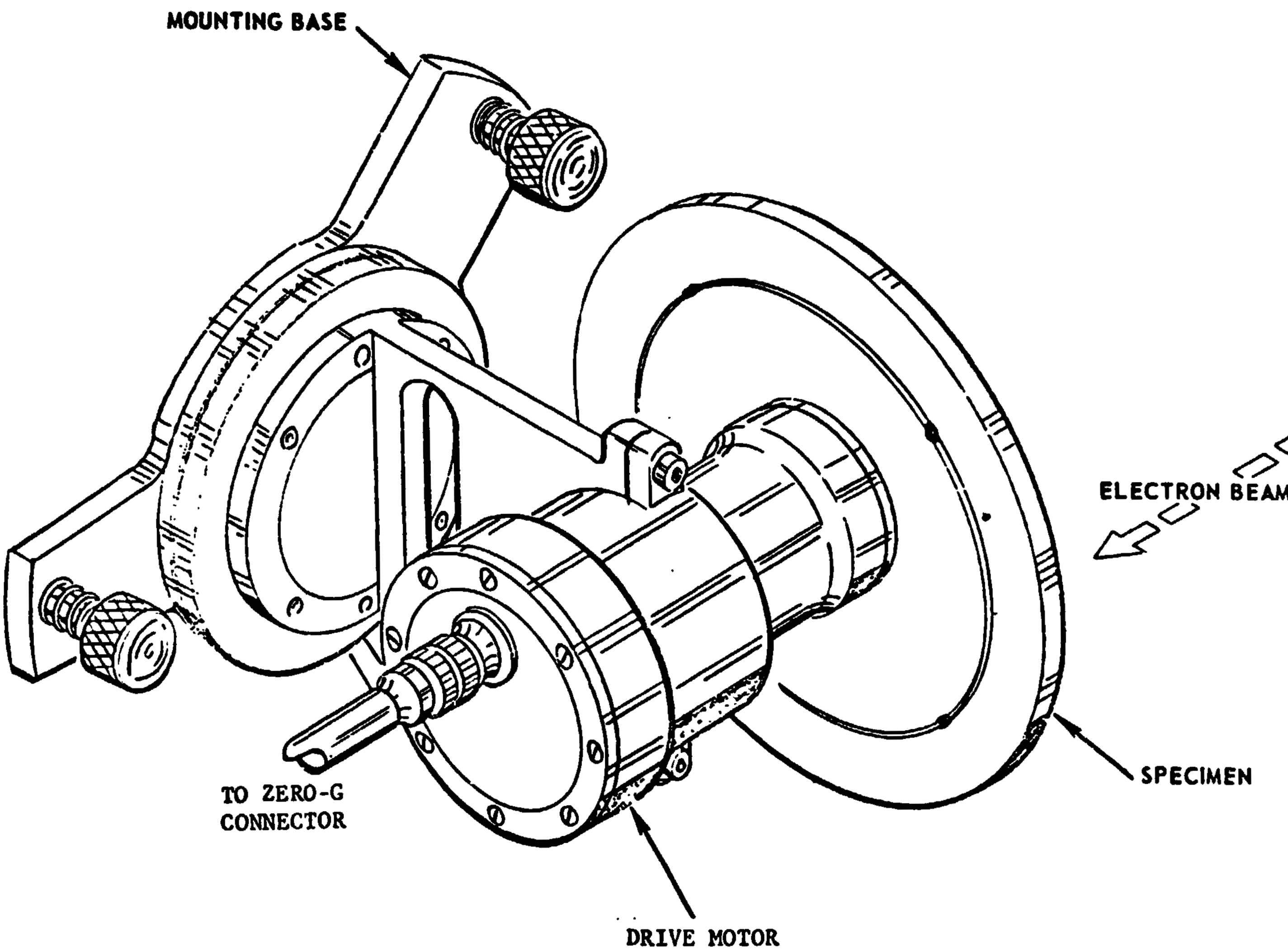


FIGURE V-12. M551 METALS MELTING ASSEMBLY (OPERATIONAL CONFIGURATION)

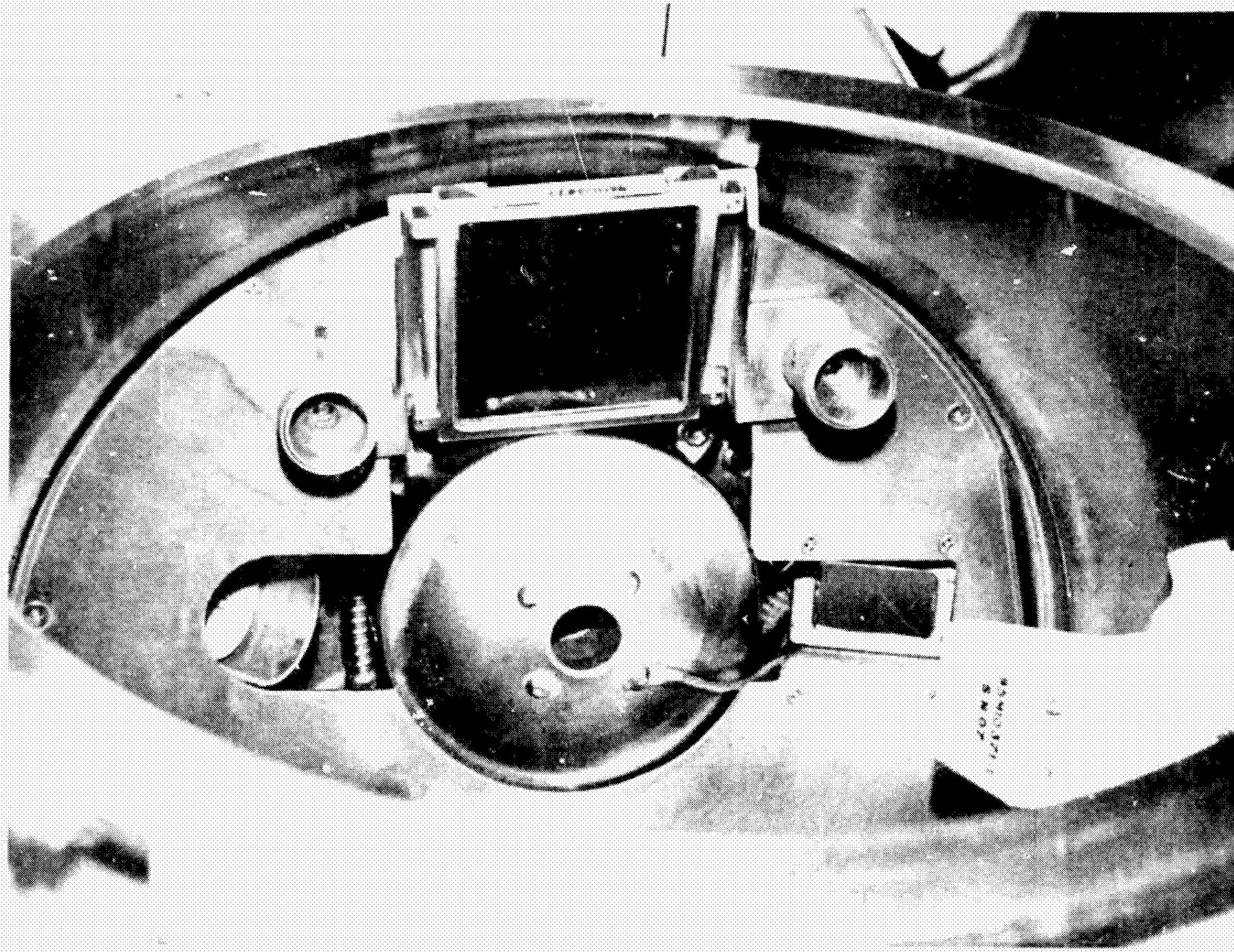


FIGURE V-13. DEFLECTION MIRROR ASSEMBLY

b. Experiment Operation. Each experiment operation involved mounting a sample disc to the M551 drive assembly (see figure V-12) and installing this in the M512 work chamber.

Physically, the M551 experiment was performed in a conventional welding test manner. The melting process was accomplished by utilizing an electron beam as a heat source and rotating the metal disc through the beam path. The beam power was about 1.6 kilowatts and the sample disc was approximately 4 cm (1.5 inches) from the electron beam port.

The beam was initially aligned on a target which was a small piece of tungsten embedded in the sample. The disc was then rotated and the metal melted to some depth along the beam's track. The molten metal at the track center became superheated with a steep temperature gradient from the center to the edge of the molten metal pool. As the disc moved through the beam, the melted metal left behind solidified very rapidly since the rest of the plate served as an effective heat sink.

Following this welding operation, the sample disc was advanced to a prescribed position and the beam allowed to impinge on one spot (dwell), without sample rotation, for a predetermined time period.

Motion pictures were taken of the melting process.

The M551 functional objective performances are summarized below:

F01 (Stainless Steel) - DOY 163 at 1740 GMT
F02 (Aluminum) - DOY 163 at 2223 GMT
F03 (Tantalum) - DOY 164 at 0030 GMT

These times are approximate, based upon crew real-time comments, voice recorded data and the published flight plan.

c. Experiment Constraints. The experiment constraints were successfully met during the mission.

d. Hardware Performance. The M551 hardware operated as designed with one exception. As the CDR prepared the chamber for the first M551 operation, he made the following report:

> "I can't account for this because I know that it was fit about ten times, but the mirror (M551 Deflection Mirror) over the electron beam gun would not fit today because the electron beam must have shifted during launch, that is the only thing that I can think of. Now is there any way that thing can move around in there or move on its adjustments, because the mirror, I got the mirror on it and you can see through it OK

by just using one screw (Calfax fastener), but it lacks fitting by a good one-eighth of an inch to the other screw because it interferes with the electron gun...I welded the plate OK, it's all right...we took photographs of it."

Malfunction analysis was immediately performed on the qual unit at MSFC. It was concluded that the problem did not involve any movement in the electron beam gun, but rather that the flight unit deflection mirror frame was improperly assembled and this assumption proved correct by examination of the 35mm photograph (see figure V-13) taken by the CDR to record this situation. The deflection mirror assembly can be seen in the upper left hand corner of the equipment storage container (figure V-9) and is shown installed in the chamber at three o'clock position in figure V-13. The photograph shows that the upper Calfax fastener is aligned as evidenced by the block alignment marks; however, the lower Calfax fastener will not align with its mounting hole as described by the CDR. The reason for this clearance problem is that the left edge of the mirror frame assembly is resting against the electron beam housing (center of photograph); therefore, the lower Calfax fastener can not be positioned far enough to the left to align with the hole. The notch machined into the right edge on the mirror frame was designed to fit over the electron beam housing to avoid this interference problem.

The CDR was correct when he stated that several fit checks had been performed; however, after the final checkout at KSC the test mirrors were replaced by the flight mirrors. The deflection mirror frame had to be disassembled to accomplish this replacement, and the frame was reassembled upside-down, or with the notch facing opposite the electron beam gun housing. This situation was not considered an anomaly, since all M551 operations were completed with no problem.

e. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission except for the deflection mirror -to-chamber interface as discussed in paragraph d.

f. Return Data. The following M551 data was returned on SL-1/2:

Three M551 sample discs.

Approximately 200 ft of 16mm type S0168 color film of the M551 operations (portions of magazines CI01, and CI03).

One 35mm photograph of the deflection mirror installation.

Crew observations of the experiment performance were voice-recorded during the mission. In addition, crew comments on the experiment were made during the SL-1/2 Crew Debriefing (June 6, 1973).

g. Anomalies. There were no anomalies associated with the M551 hardware.

4. Experiment M552-Exothermic Brazing. The Principal Investigator for Experiment M552 is Mr. James R. Williams, Process Engineering Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. The experiment hardware was developed by the Process Engineering Laboratory, MSFC, Huntsville, Alabama.

a. Experiment Description

(1) Objective. The objectives were to test and demonstrate a method of brazing components for space assembly and repair/maintenance operations; and study surface wetting and capillary flow effects in molten metals while in a weightless environment.

(2) Concept. The experiment was to produce four simulated joints by brazing sleeves of similar material over tubes that were slit through most of their cross section. The heat required to melt the braze alloy was to be supplied by exothermic (heat-producing) materials. The clearance (gap) between the sleeves and tubes was to be varied to produce optimum and extreme brazing conditions.

(3) Hardware Description. The M552 exothermic package (see figure V-14) was the only M552 hardware item. This package was a stainless steel container that contained the four braze samples (tubes) and was electrically connected to the M512 battery through the zero-g connector inside the chamber. The package attached to the chamber heat sink flange with two Calfax fasteners.

A brief description of the package construction is included to aid the understanding of the experiment function. Each sample was a metal tube 1.9 cm (0.75-in.) diameter by 0.12 cm (0.049 in.) wall thickness with two sample tubes constructed of stainless steel and two of nickel. A small segment of the braze ring in the nickel tubes was irradiated with an Ag-110 isotope for post-flight evaluation of the metal flow patterns.

A slit was cut around the tube perimeter, leaving enough of the perimeter uncut to provide tube support on each side of the slit. The slit purpose was to simulate two separate tubes butted together. Surrounding the simulated joint was a stainless steel or nickel sleeve that was to be brazed to the tube. The braze alloy (silver-copper-lithium) was in the form of two preformed rings set in grooves around each specimen tube. Each specimen tube assembly was installed into

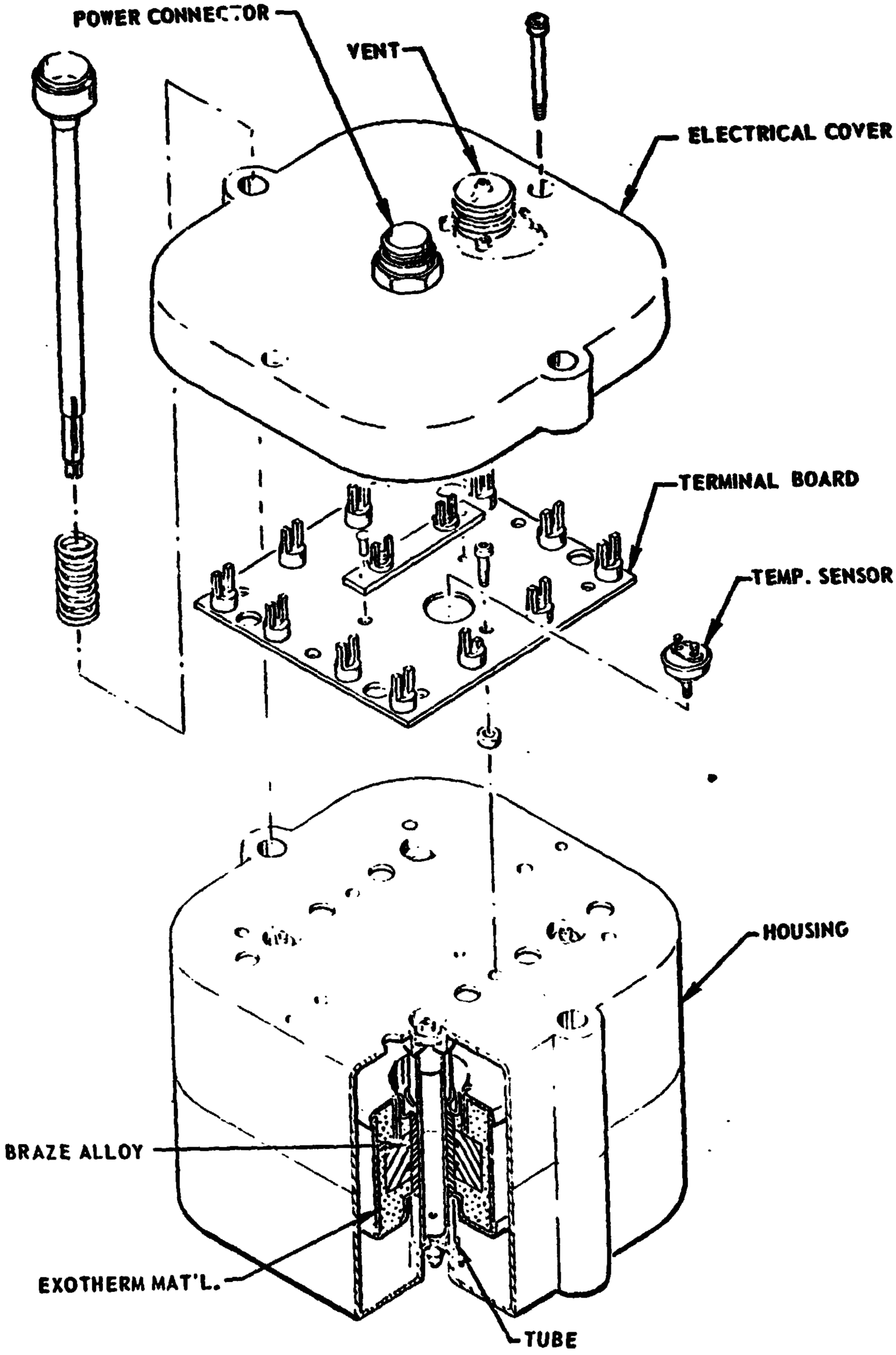


FIGURE V-14. EXOTHERMIC BRAZING PACKAGE

a cylinder that contained an exothermic (heat producing) material and an electrical igniter which was placed in one end of the cylinder to ignite a chemical mixture which in turn heated the exothermic mixture to its ignition point. Substantially all of the reaction products were solid, and no external oxygen supply was required for the reaction.

The crewman handled only the assembled container and the internal operations were not visible to him.

b. Experiment Operation. The M552 experiment operations involved package installation into the M512 work chamber and chamber evacuation to space vacuum (zero pressure on the work chamber vacuum gauge). The sample ignition was initiated by actuation of the control panel trigger switch. Approximately 90 seconds were required for the complete reaction with approximately two hours and forty-five minutes required for sample cooling. Each sample ignition and cooldown was a separate functional objective (FO). After package installation and FO1 initiation, the crewman was only required to return at predetermined times to initiate the remaining FOs.

The M552 experiment operation was performed by the SL-2 crew as a shopping list item and not scheduled into the SL-2 timeline. All four M552 samples were completed. The approximate completion times were as follows:

FO1 - DOY 166 at 1745 CDT

FO2 - DOY 167 at 0300 CDT

FO3 - DOY 167 at 0900 CDT

FO4 - DOY 167 at 1200 CDT

(Times noted above are approximate based upon crew real-time voice comments.) The crew stated that the M552 terminate checklist was complete and the M512 battery discharge initiated at 2010 GMT on DOY 167.

c. Experiment Constraints. The experiment constraints were successfully met during the mission.

d. Hardware Performance. The M552 Exothermic Package performed as designed with no discrepancies.

e. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

f. Return Data. The only physical data returned was the M552 exothermic package. Crew observations and comments were made during the mission and at the SL-1/2 Crew Debriefing (June 6, 1973).

g. Anomalies. There were no anomalies associated with the M552 hardware performance.

5. Experiment M553 - Sphere Forming. The Principal Investigator for Experiment M553 is Mr. Earl A. Hasemeyer, Process Engineering Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. The experiment was developed by the Process Engineering Laboratory, MSFC, Huntsville, Alabama.

a. Experiment Description

(1) Objective. The objective was to demonstrate zero-g and space vacuum effects upon solidification of: a pure nickel at undercooling not possible to achieve on earth; a nickel-tin alloy having a wide freezing range; a nickel-silver alloy having a narrow melting range which cores on solidification; and a nickel-copper alloy having a wide melting range but essentially no difference in density between the two elements.

(2) Concept. The concept was to melt small metal samples and allow these samples to resolidify under zero-g conditions. The metal sample was to be released from its holder to free-float during resolidification, allowing examination of surface tension effects on the solidification processes. Theoretically the surface tension forces should cause the molten metal to take a spherical shape when solidified.

The M512 electron beam gun was to be used as the heat source and each sample placed in the beam path for heating.

(3) Hardware Description. The hardware consisted of the following:

(a) Sphere forming assembly. The sphere forming drive assembly positioned and indexed the specimen wheel as required through the electron beam path for melting. The drive assembly consisted of the tripod mounting base that attached to the heat sink flange and an "indexing" electric motor. Figure V-15 illustrates the drive assembly with a sample wheel attached to the motor output shaft, and figures V-6 and V-7 show this complete experiment assembly (drive assembly and sample) installed in the chamber. The sample was approximately 15 cm (6 inches) from the electron beam port.

The stowage position is shown in figure V-9.

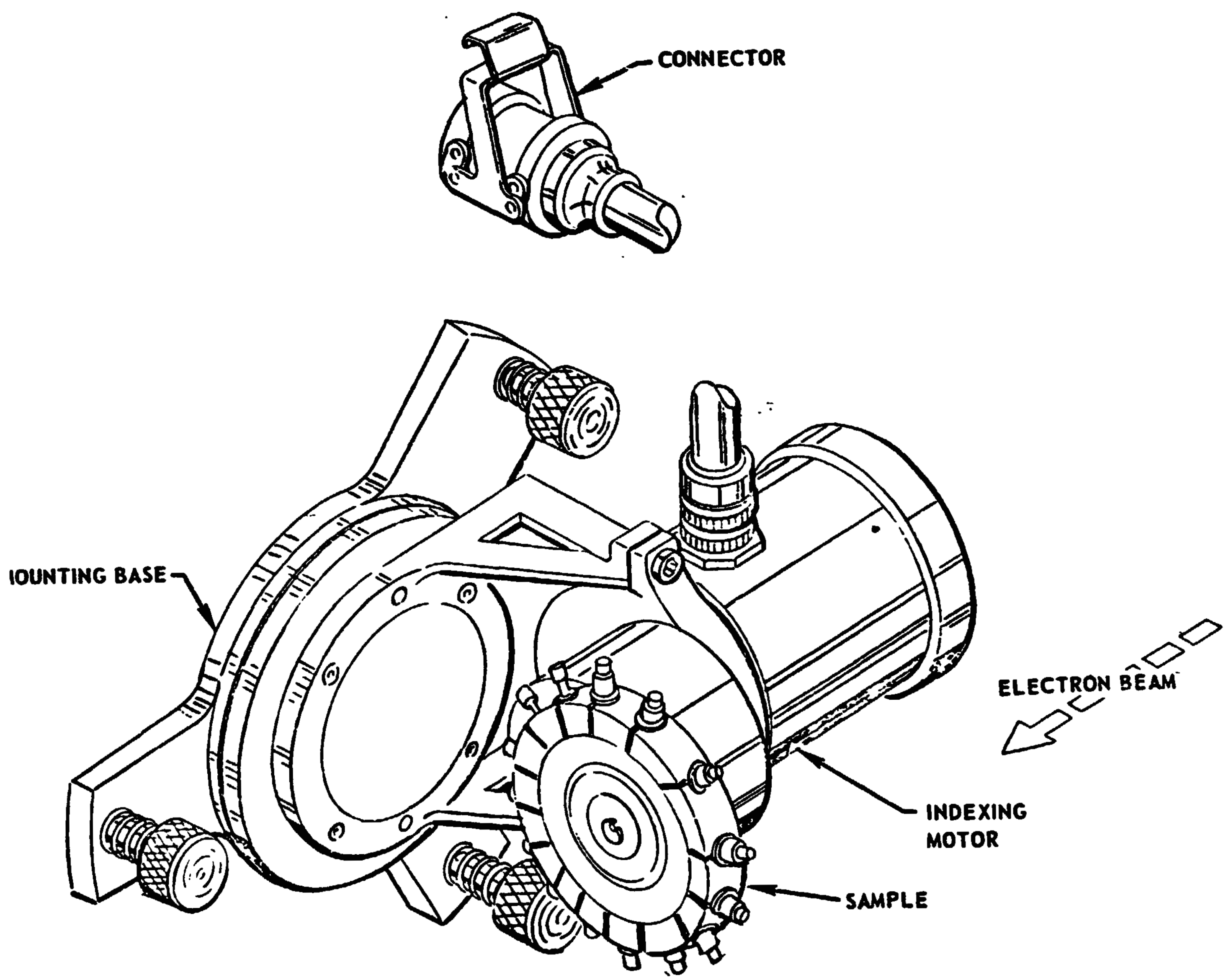


FIGURE V-15. M553 SPHERE FORMING ASSEMBLY (OPERATIONAL CONFIGURATION)

The indexing motor was a +28 VDC electric motor with a gear-type speed reducer. A cam arrangement on the output motor shaft operated a ratchet mechanism which advanced the specimen wheel 24 degrees $\pm$ 20 minutes rotation per index cycle. The motor operation was controlled by a three-position switch on the M512 control panel.

(b) Specimen wheel assembly. The experiment samples were contained on two specimen wheels (see figures V-9 and V-16). Each M553 specimen wheel was a pinwheel having fifteen spokes or positions for samples. The first position contained the tungsten target (see figure V-16 at the 3 o'clock position) used for the electron beam gun alignment. The next three positions contained small cylindrical samples attached to the wheel by thin cylindrical metal rods (see figure V-16)at the four, five and six o'clock positions). These samples remained mounted after resolidification until cut from the wheel by the crewman. The third sample is shown removed in figure V-16 to illustrate the mounting rod. The remaining eleven positions contained samples, each mounted to a ceramic post by a small metal rod (called a sting). The sting was retracted from the molten sample by a spring, allowing the sample to resolidify in a free-floating state. Also, this sting retraction automatically removed power from the electron beam gun regulator and deflection coils.

Each sample wheel contained four pure nickel samples, four nickel/12% tin alloy samples, four nickel/1% silver alloy samples, and two nickel/30% copper alloy samples.

(c) Sphere catcher. The sphere catchers were small metal cups 3.8 cm (1.5 inches) in diameter and 5 cm (2 inches) long, with 144 small holes drilled in the side and bottom. The cup assemblies fit inside the small vacuum cleaner port located at the chamber bottom (see figure V-5). The cup assembly was inserted in the work chamber prior to the experiment operation. The vacuum cleaner was attached to the port after the operation was completed and the chamber had been repressurized. The hatch was cracked and the vacuum cleaner started, resulting in an airflow from the chamber top to bottom. Theoretically, this airflow would pull the small floating spheres to the vacuum cleaner port, where they would accumulate in the sphere catcher cups.

(d) Sphere catcher installation tool. The sphere catcher installation tool was a machined insert that attached to the sphere catcher assembly for handling purposes.

b. Experiment Operation. The first specimen wheel (F01) was installed in the work chamber prior to DOY 164 sleep period. The work chamber was evacuated to space vacuum (using the VENT position of both vent valves) during the sleep period to establish a proper vacuum for the first operation.

FIGURE V-16. M553 SPECIMEN WHEEL AND SAMPLES

At 1500 GMT, DOY 164, the CDR reported that he had performed the initial electron beam gun alignment for operation. He stated that the vacuum had reached 1 x 10^{-5} torr in the work chamber, but that he had experienced difficulty in performing proper alignment and that outgassing was causing the vacuum level to degrade. The possible outgassing cause was discussed and it was concluded to be a normal situation due to the tungsten target outgassing level. In addition, any contamination ionization on the sphere forming assembly could also have caused vacuum degradation.

The 16mm film coverage of the operation began with the third permanently mounted sample and it is not clear why there is no film coverage of the tungsten target alignment and the first two sample melting operations. However, a film review of the first specimen wheel did indicate that the electron beam was aimed too close to the sample mounting sting interface.

F01 operations were started at 1615 GMT, DOY 164. The CDR reporting (1701 GMT) on the first specimen wheel operation described the successful completion of the first three samples and stated that the electron beam gun automatically turned off after one second of the normally five-second melt time on the fourth sample. The flight films revealed that the electron beam struck the ceramic post, which could have melted the nichrome wire inside the post, resulting in automatic electron beam cutoff. The CDR reiterated that the vacuum level continued to degrade during electron beam gun operation. He stated that whenever the filament chamber pressure gauge reading approached 0.1 (1 x 10^{-4} Torr), he would terminate electron beam gun operation in accordance with the checklist and wait for the pressure level to decrease.

Experiment operations on specimen wheel 1 were completed at approximately 1300 GMT (DOY 165) and specimen wheel 2 operations were begun at approximately 1749 GMT (DOY 165). After completion of seven samples, F02 operations were terminated at 0022 GMT (DOY 166) for the reasons discussed in subsection 1.d.

c. Experiment Constraints. The experiment constraints were successfully met during the mission.

d. Hardware Performance. The hardware operated essentially as expected with two minor exceptions. The first exception involved the sample release and early beam cut-off already discussed in paragraph 5.b. The second exception concerned the sample retrieval method. The CDR reported during the crew debriefing that the samples that did release from the wheel were found attached to the motor housing instead of in the sphere catcher. The vacuum cleaner retrieval method did not pull any samples into the sphere catchers.

The CDR had to manually retrieve all the samples and place them into the sphere catchers. The most likely cause is that the motor created enough magnetism to attract the floating metal spheres.

e. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

f. Return Data

(1) Skylab 1/2. All fourteen samples from specimen wheel 1 were returned for evaluation. The fourteen samples (seven processed, seven unprocessed) including specimen wheel 2 were returned for evaluation. Approximately 200 feet of 16mm type S0168 color film of the M553 operations were returned (portions of magazines CI01, CI03, CI07). Crew observations were voice recorded during the mission and some crew comments were made during the SL-1/2 Crew Debriefing (June 6, 1973).

(2) Skylab 3. Specimen wheel 1 was returned for evaluation.

g. Anomalies. There were no anomalies associated with the M553 hardware.

6. Experiment M555 - GaAs Crystal Growth

NOTE: Experiment M555 was not performed during the Skylab Program. This discussion is included for information pertaining to the experiment and documents the reasons why it was not launched.

The Principal Investigator for Experiment M555 is Mr. Mirt C. Davidson, Space Science Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. The experiment was developed by the Process Engineering Laboratory, MSFC, Huntsville, Alabama.

a. Experiment Description. Growth of crystals from metallic solutions appears to offer a valuable method of producing high quality material; however, thermally-driven convection currents had heretofore introduced difficulties. This problem would, of course, be eliminated in zero-g conditions.

(1) Objective. The objective was to grow single crystals of gallium arsenide from solution in near-zero-g, in anticipation of producing material of exceptionally high chemical and crystalline perfection.

(2) Concept. The heart of the experiment was to be the growth ampoule, a fused quartz tube containing the source, solvent, silicon dopant, and seed. In general, the source material, chunks of high-purity gallium arsenide (GaAs) were to be dissolved in liquid

gallium metal at the hot end of the elongated ampoule, then transported by diffusion down the ampoule, and finally deposited on a seed at the colder end of the ampoule. The experiment was to consist of a pure GaAs layer grown on a pure seed (ampoule 1), a pure GaAs layer grown on a doped seed (ampoule 2), and a doped GaAs layer on a pure seed (ampoule 3).

(3) Hardware Description. The three experiment ampoules were packaged in a cylindrical container (furnace) 10 cm (4 inches) diameter by 29 cm (11.5 inches) in length. The furnace was stored in the launch container (see figure V-17) at all times except during the actual experiment operation.

The launch container supplied the heated environment required to maintain the ampoule contents in the liquid state before and after the crystal growth process. The launch container had dimensions of 46 cm (18 inches) by 20 cm (8 inches) by 28 cm (11 inches) and weighed 9.1 kg (20 lb) with the furnace installed. An electrical connector was provided to interface with both the CM and MDA. The container was launched in the CM, where 3 watts (at +28 VDC) of continuous power were required. After docking, the container was transferred to its storage position on the M512 mounting panel (see figure V-2), and electrically connected to the AM Power Bus until experiment performance.

b. Experiment Operation. The operational sequence would have involved the furnace removal from the launch container and insertion into the M512 chamber heat sink cavity. The furnace was to be connected using the zero-g connector, and experiment operation initiated by activation of a control panel switch. The subsequent operation time (115 hours) would not have required crew participation.

(1) Skylab 1/2. The hardware was scheduled to be launched on the Skylab 2 CM and performed in the M512 chamber during this mission. However, due to the SL-1 launch anomaly, the launch container was removed from the SL-2 CM to provide additional launch space for the contingency equipment.

(2) Skylab 3. Approval was obtained for launch and performance of M555 on the SL-3 mission, and the launch container was stowed in the CM. However, at the SL-3 Flight Readiness Review on July 24, 1973, NASA removed the container to allow easier stowage of the contingency rate gyro "six pack" hardware.

(3) Skylab 4. The hardware was included on a priority list for launch on the SL-4 CM; however, the hardware was not launched on SL-4. The experiment hardware is currently stored at MSFC in the event that a future program may provide an opportunity for performance.

FIGURE V-17. M555 FURNACE IN LAUNCH CONTAINER

B. Multipurpose Electric Furnace Experiments

1. M518 - Multipurpose Electric Furnace System. The Principal Investigator for the M518 system is Mr. Arthur Boese, Process Engineering Laboratory, George C. Marshall Space Flight Center, Huntsville, Alabama. The MSFC had responsibility for program and technical management for the M518 system and eleven associated experiments.

The system developer was Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. System Description. The Multipurpose Electric Furnace System (MEFS) was not considered to be an experiment, but rather a facility in which other experiments could be performed. These are:

Experiment M556--Vapor Growth of IV-VI Compounds
Experiment M557--Immiscible Alloy Compositions
Experiment M558--Radioactive Tracer Diffusion
Experiment M559--Microsegregation in Germanium
Experiment M560--Growth of Spherical Crystals
Experiment M561--Whisker-Reinforced Composites
Experiment M562--Indium Antimonide Crystals
Experiment M563--Mixed III-V Crystal Growth
Experiment M564--Halide Eutectics
Experiment M565--Silver Grids Melted in Space
Experiment M566--Aluminum-Copper Eutectic

(1) Objective. The objective was to provide an extension of existing Skylab hardware capabilities which would enable an experiment series to be performed on solidification, crystal growth and other processes involving material phase changes at elevated temperatures in a near zero-g environment.

(2) Concept. The system was to be designed to apply the widest possible prescribed heating and cooling programs and/or controlled temperature distributions to chosen material samples within the constraints of the existing Skylab interfaces.

(3) Hardware Description. The MEFS was comprised of the following items:

Electric furnace;
Control package;
Power and TM cable;
Hermetic lead cable;
Cartridge container A;
Cartridge container B;
Thermal grease tube; and
Contingency cartridge hook.

The three main system parts were: the furnace; a programmable electronic temperature control package; and the experiment cartridges (see figures V-18 through V-21).

The furnace had three specimen cavities in which three material sample cartridges were processed in a single run. The furnace construction provided three different temperature zones along each sample cavity length as follows:

A programmable constant-temperature hot zone at the sample cavity end where temperatures up to 1050°C were reached.

A gradient zone adjacent to the hot zone where temperature gradients ranging from 20°C to 200°C per centimeter were established in the samples.

A cool zone in which heat conducted along the samples was rejected by radiation to a conducting path that removed heat from the system.

The control package controlled the furnace temperature to any specified temperature within the furnace's capability. Two timing circuits in the control package permitted programming the soak time spent at the set temperature and the furnace cooling rate at the end of the soak period. (Active temperature control continued during programmed cooling.)

The experiment material samples were enclosed in stainless steel cartridges of similar size (2.1 cm dia. by 20.2 cm long) for insertion into the furnace. The cartridge thermal design further controlled the actual temperature distribution applied to the sample.

The two cartridge containers provided stowage for the 33 sample cartridges (11 experiment sets). In addition, the system included: cables which interconnected the system, and connected the system to power and data outlets, a tube of thermal grease and a contingency cartridge extraction tool.

b. Experiment Operation. The MEFS was launched on SL-1. No experiment operations were planned for SL-2.

(1) SL-3 Operation. The M518 experiments were originally scheduled to be performed during the SL-4 mission, but as mission time was available and the crew requested additional work, approval was granted to perform as many M518 experiments as possible during the SL-3 mission. Subsequently, a revised checklist was sent to the crew on DOY 249. Although the crew was not trained to perform M518, the PLT was involved in initial hardware design and was trained to perform a similar experiment, M555, GaAs Crystal Growth.

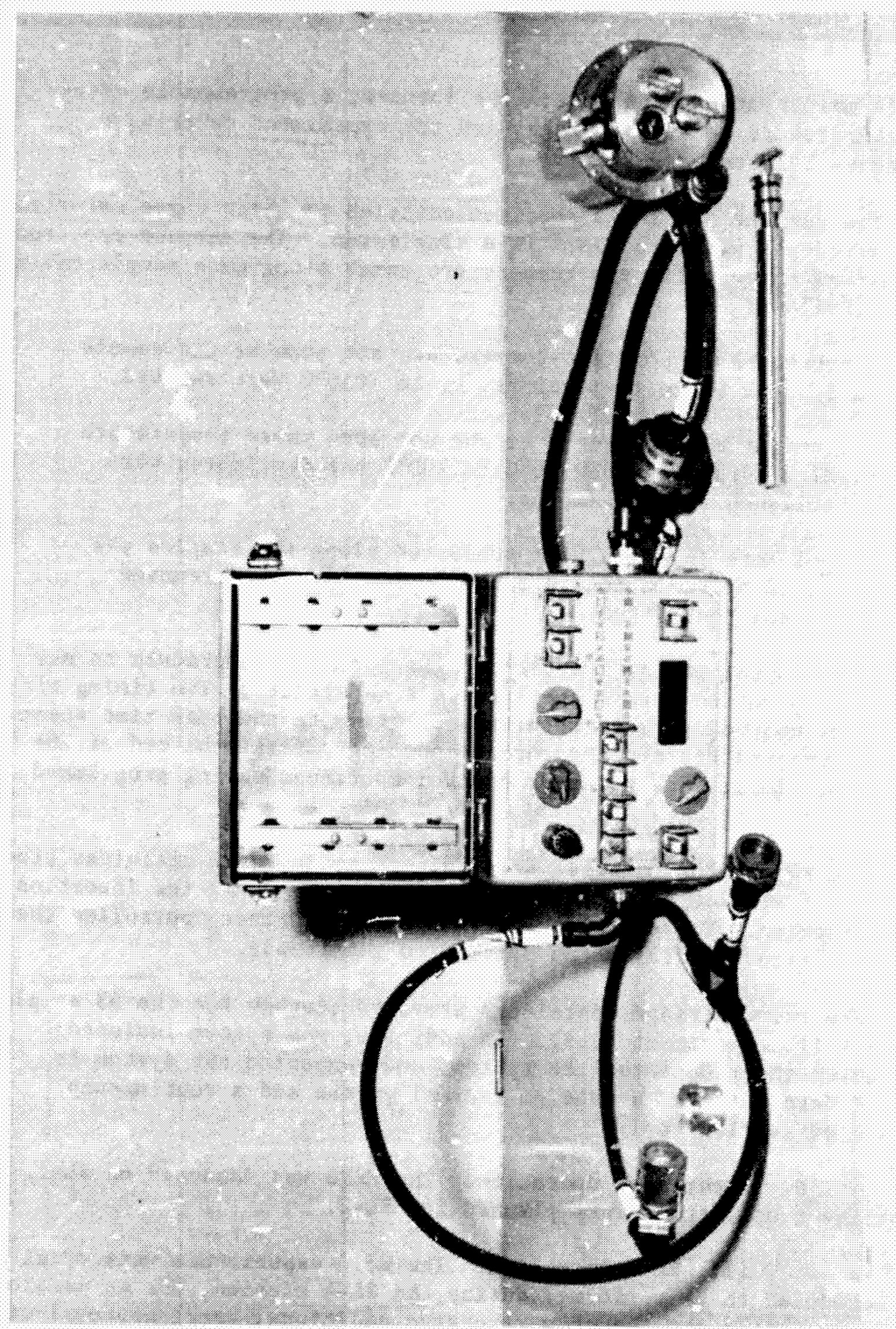


FIGURE V-18. MULTIPURPOSE ELECTRIC FURNACE SYSTEM

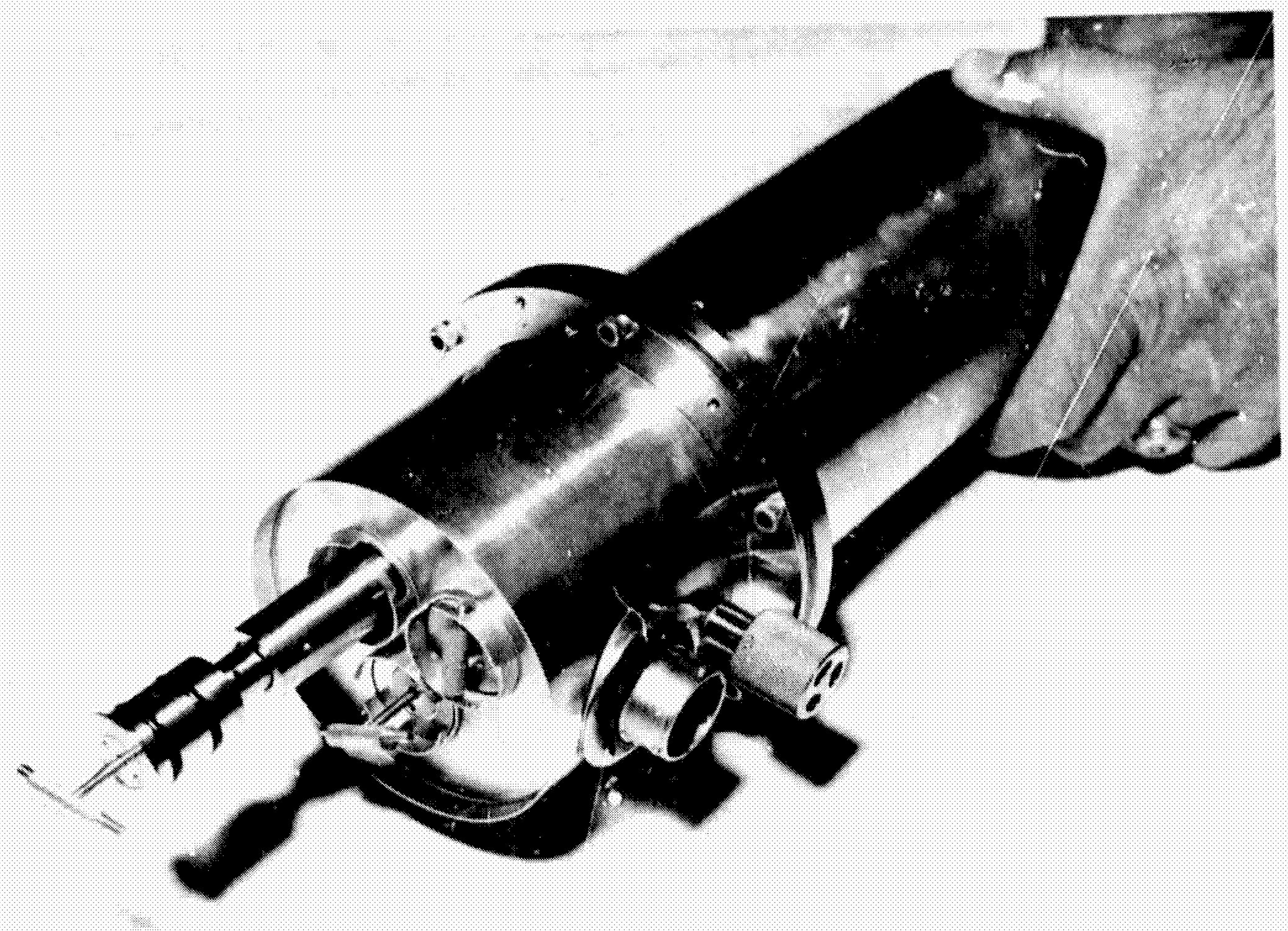


FIGURE V-19. MULTIPURPOSE ELECTRIC FURNACE

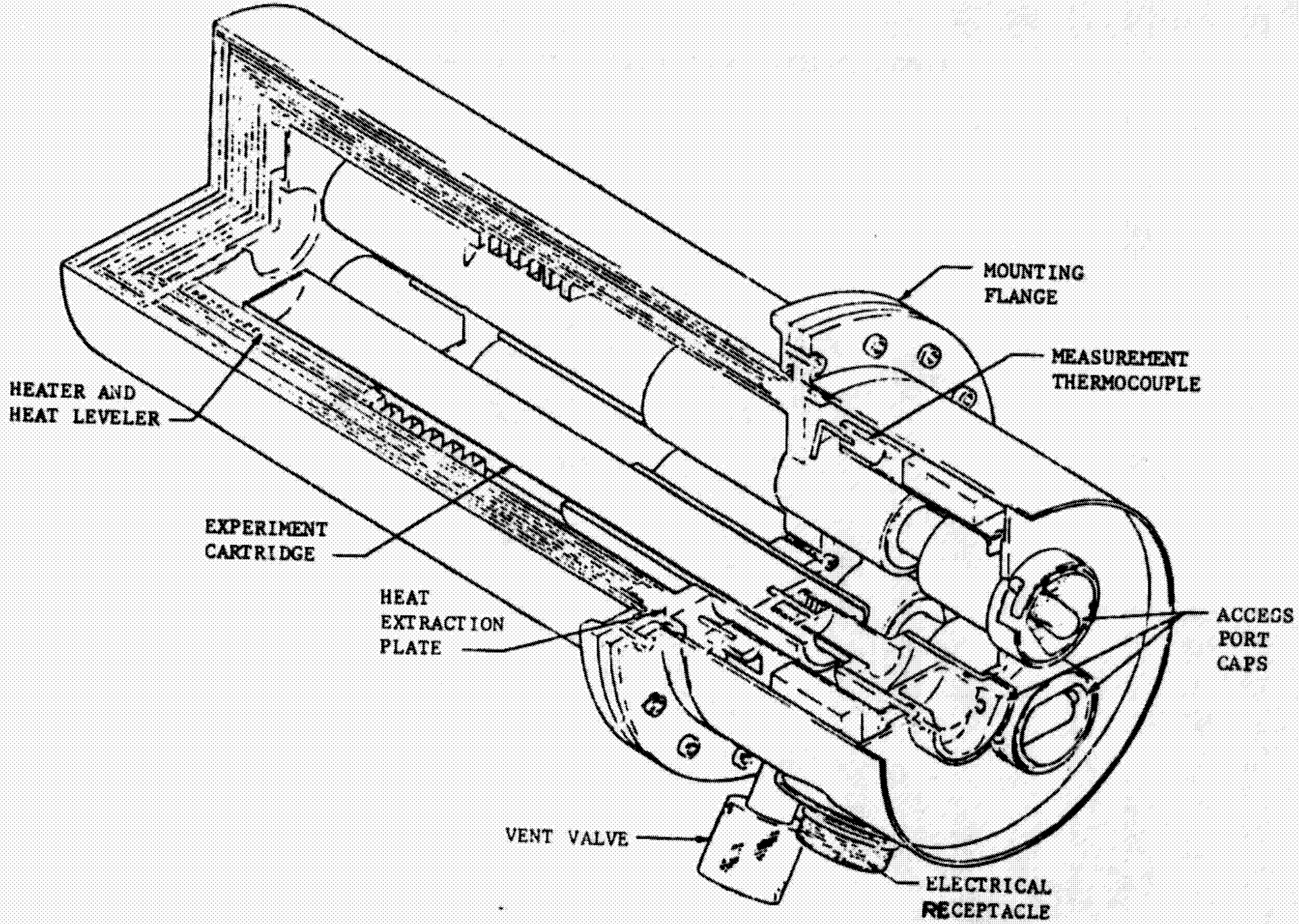


FIGURE V-20. CUTAWAY VIEW OF MULTIPURPOSE ELECTRIC FURNACE

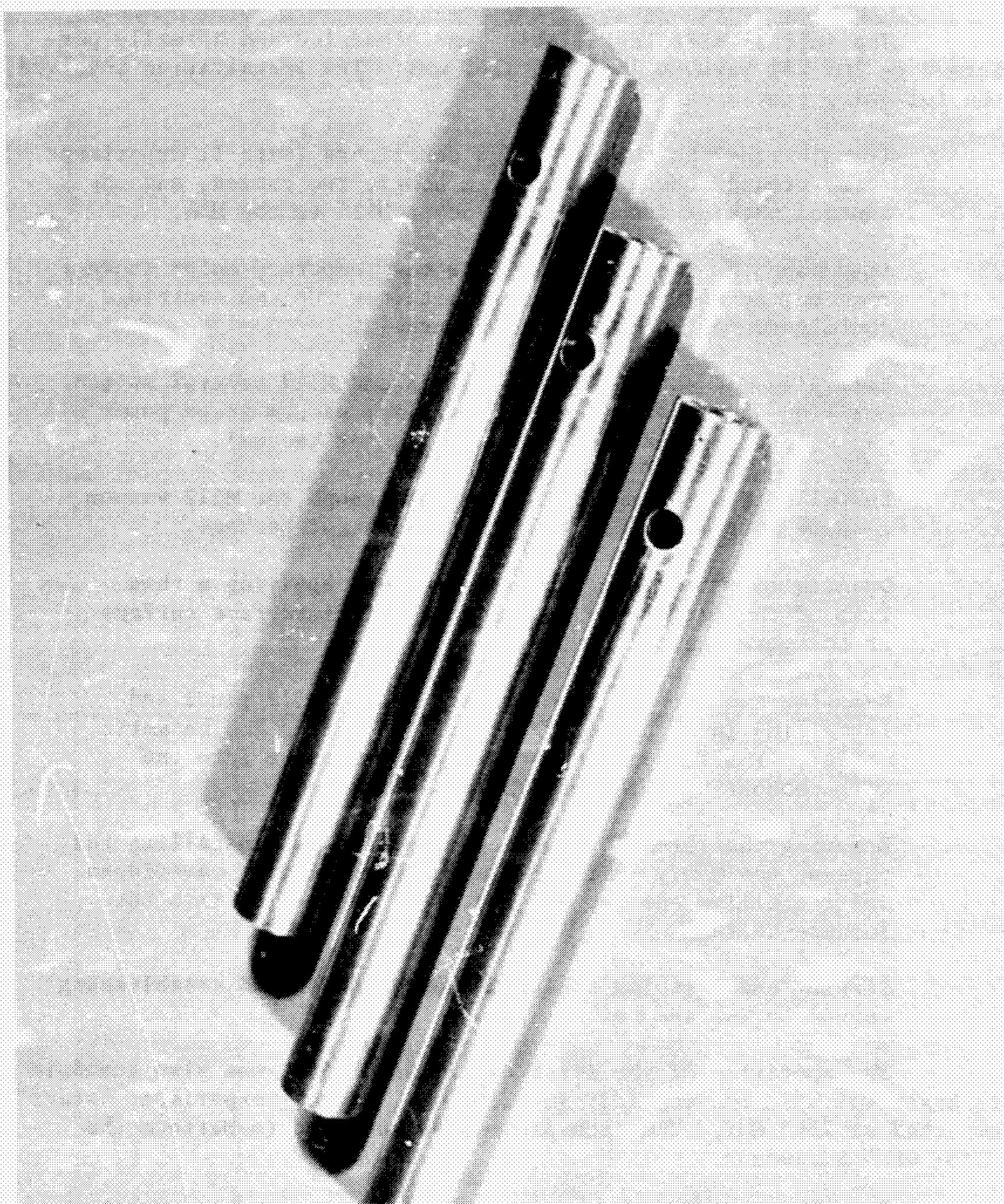


FIGURE V-21. TYPICAL EXPERIMENT CARTRIDGE SET

The initial MEFS installation was scheduled and actually performed on DOY 251 between 1657 and 1747 GMT. The installation involved the following procedures:

Transferring the two cartridge containers (with 11 experiment sets, grease tube and cartridge hook), two cables, and the control package from the OWS locker D416 to the MDA.

Attaching the control package to the temporary motor stowage ring on the M479 flammability container and the cartridge containers to the M552 mounting bracket.

Verifying the two MDA vacuum valves and M512 control switch positions and installing the auxiliary vacuum gauge power cable (used to measure M512 work chamber vacuum).

Installing the hermetic lead cable through the M512 vacuum cleaner port and connecting to the control package.

Opening the M512 work chamber hatch and applying a thin film of thermal grease to the heat sink interface surface of the work chamber heat sink.

Removing the furnace from stowage on the M512 panel and installing into the work chamber, connecting the hermetic cable to the furnace and securing the furnace into the work chamber with the M555/M518 clamp.

Removing the three furnace access port caps, installing the caps on the M557, Immiscible Alloy Composition, cartridges and installing the cap and cartridge assemblies into the furnace ports.

Closing and latching the work chamber hatch and establishing vacuum in the chamber.

The operation of the first experiment, M557, was also scheduled to begin DOY 251, between 2039 and 2100 GMT. Actual experiment "start" occurred at 2105 GMT. The crew procedures required to perform the "M557 OPS" included:

Reconfiguring the video tape recorder (VTR) to allow M518 to use the MDA hi-power outlet 115. (The VTR was powered from OWS outlet 402 via two high-power accessory outlet cables.)

Connecting the M518 power and TM cable to the control package, MDA hi-power outlet 115, and SIA 116 channel B.

Turning "ON" the hi-power outlet, the M512 crystal growth heating pad AM Bus 1 circuit breaker (power to the M512 vacuum gauge), and the M518 control package.

Performing the M518 lamp test and setting the soak temperature, soak period, cool-down rate, and proper heaters for the M557 experiment.

Verifying that the M512 vacuum chamber had reached the proper vacuum level (5×10^{-4} torr max) and initiating experiment operation.

The M557 experiment continued to operate automatically and unattended (except for early crew monitoring of furnace temperature and vacuum) and was successfully completed on DOY 252 at approximately 2250 GMT. The actual scheduled time for M557 termination and set-up for M562, Indium Antimonide Crystal Growth, was DOY 252, between 2230 and 2250 GMT. The procedures required to exchange experiment cartridges were as follows:

Verify the furnace was at "touch temperature", i.e., less than 46°C (digital display and status indicator on control package).

Closing the two MDA vent valves, repressurizing the M512 chamber, and opening the chamber hatch.

Removing the three cartridges from the furnace and replacing into the cartridge container, latching end first, and installing the next experiment set of cartridges into the furnace.

Closing and latching the M512 chamber hatch and establishing vacuum in the work chamber.

As the M512 experiments had experienced problems in maintaining vacuum in the chamber, (reference paragraph A.1.d), the PLT was asked to determine the time required to achieve a vacuum level of 5×10^{-4} torr in the work chamber during the M562 experiment preparations. The PLT reported that it took nine minutes to achieve this vacuum level. (Subsequently, at the SL-3 Experiment Crew Debriefing, the PLT, when asked to elaborate on vacuum levels, stated that the vacuum level instantaneously, after opening the vent valves, reached 2×10^{-3} torr. He reported that he only measured the time-to-vacuum once, as requested, but observed that the time-to-vacuum was essentially the same each time he drew vacuum on the system.)

The successful operation of M562, as well as the balance of the eleven M518 experiments was as follows:

M562 - DOYs 253 and 254
M566 - DOYs 254 and 255
M564 - DOYs 255 and 256
M559 - DOYs 256, 257, and 258
M563 - DOYs 258 and 259
M561 - DOYs 259 and 260
M560 - DOYs 260 and 261
M565 - DOYs 261 and 262
M558 - DOYs 262 and 263
M556 - DOYs 263, 264, and 265.

For details on the operation times for each experiment refer to paragraphs 2 thru 12.

Following M556 completion on DOY 265, the M518 system remained installed at the operational location except that the power and TM cable was disconnected and stowed in the M512 accessories box. The thermal grease and the contingency cartridge hook were stowed in the accessories box after removal from the cartridge containers rather than being discarded as required by the on-board procedures. The two cartridge containers, with 33 cartridges, were returned in the SL-3 CM for evaluation.

(2) SL-4 Operation. After having successfully completed all eleven M518 experiments on SL-3, requests were submitted for approval to launch and perform the M518 flight backup experiments on SL-4. Approval was obtained to launch as many M518 cartridge sets as possible consistent with the SL-4 CM weight and volume constraints. Seven backup cartridge sets without any cartridge containers were launched in the SL-4 CM. Each cartridge set was stowed for launch in a bag which in turn was placed in a temporary stowage bag snapped to the M512 accessories box.

The initial operation of the MEFS during SL-4 was on DOY 355, between 1340 and 1425 GMT. During this time period the crew performed the following procedures:

Verified the MDA vacuum valve and M512 control switch positions

Obtained and installed the M518 power and TM cable

Reconfigured the VTR to allow M518 to use MDA hi-power outlet 115 (the VTR was powered from OWS outlet 402 via two high power accessory cables)

Opened the M512 work chamber hatch and installed the three M557 cartridges into the furnace

Turned ON the hi-power outlet, M512 crystal growth heating pad AM Bus 1 circuit breaker, and M518 control package

Performed the M518 lamp test and set the soak temperature, soak period, cool-down rate, and proper heaters for the M557 experiment

Verified that the M512 vacuum chamber had reached the proper vacuum level (5×10^{-4} torr max) and initiated experiment operation.

The actual M557 experiment turn-on did not occur until 1900 GMT because of the time necessary to vent the M512 work chamber to a vacuum level of 5×10^{-4} torr. Once initiated, the M557 experiment continued to operate automatically and was successfully completed on DOY 357 at 2040 GMT.

The successful operation of the other SL-4 M518 experiment was as follows:

M560 - DOY 361
M561 - DOY 362 and 363
M563 - DOY 364, 365 and 001
M566 - DOY 004 and 005
M562 - DOY 005 and 006
M556 - DOYs 006, 007, 008 and 009

For details on the operation times for each experiment refer to paragraphs 2 thru 12.

It was noticed during the operation of the first few experiments that the initiation did not occur when scheduled. The crew was asked if they were having problems with the experiment operation. They responded that the hardware worked fine, but they were experiencing difficulty obtaining the proper vacuum level. It was learned that the time to obtain a vacuum level of 5×10^{-4} torr on the SL-4 mission was between 45 and 90 minutes rather than the nine minutes experienced during SL-3 operation. With this information, the remaining experiments were scheduled to allow sufficient time to reach 5×10^{-4} torr vacuum prior to the initiation of an experiment.

Following M556 completion on DOY 009, the MEFS was removed from its operational location and returned to the original stowage locations. The seven experiment cartridge sets (21 cartridges) were placed in the SL-4 CM for return to earth.

c. Constraints. The experiment constraints were successfully met during the SL-3 mission except the following MRD constraint:

"It is highly desirable that the initiation of Experiments M563, M561, M566, M560, M559, M565 and M558 be scheduled within one hour preceding the start of crew sleep periods to minimize crew motion during experiment solidification

and to maximize the AM Bus voltage for the experiments requiring the highest power."

This constraint was intentionally not adhered to so that all eleven experiments could be scheduled and performed on the SL-3 mission.

All experiment constraints were successfully met during the SL-4 mission.

d. Hardware Performance.

(1) SL-3 Performance. Each of the eleven experiments was comprised of three cartridges, each experiment set was processed under identical thermal conditions by the MEFS. The MEFS performed as designed with two exceptions, neither of which created a problem nor was considered an anomaly.

The first exception was that the furnace heat-up times were generally much shorter than expected. The following table presents the expected and actual heat-up times for each experiment in order of performance.

Experiment \ Heat-Up Time (hours)	Preflight Estimate	Actual
M557	4.8	4.6
M562	2.8	1.9
M566	4.8	2.7
M564	3.8	2.5
M559	4.5	3.3
M563	3.0	2.9
M561	6.7	3.6
M560	1.5	1.3
M565	5.0	3.6
M558	2.0	2.1
M556	3.0	2.3

The faster heat-up time was explained by the AM Bus 1 voltage during the inflight operation being higher than the voltage used to estimate the furnace heat-up times. The bus voltage was monitored throughout system operation and averaged between 28.6 and 28.7 VDC, whereas preflight heat-up time estimates were based upon a maximum of 28 VDC. The faster heat-up times actually helped in accomplishing all eleven experiments on the SL-3 mission as a shorter total operation time was required.

The second exception to the MEFS expected performance was an apparent slip or change in resistance of the soak temp potentiometer. This phenomenon was observed during the performance of the first

three experiments (i.e., M557, M562 and M566) when the desired soak temperature was not achieved. The following table presents this data.

Experiment	Soak Temp Setting	Desired/Expected Soak Temp (°C)	Actual Soak Temp (°C)
M557	725	732	724
M562	795	804	794
M566	855	867	849

The decrease in the soak temperature did not significantly affect the experiment performances since it only shortened the melt-back of the sample material by a few millimeters. After reviewing the data obtained from the three experiments performed, it was decided to increase the potentiometer settings for the remaining experiments. This was accomplished by advising the crew to change the potentiometer settings in the on-board checklist to the revised values. The following table presents the data obtained for the remaining experiments in order of performance.

Experiment	Original Soak-Temp Setting	Revised Soak Temp Setting	Desired Soak Temp (°C)	Actual Soak Temp (°C)
M564	895	915	911	926
M559	985	995	1005	1012
M563	950	960	966	976
M561	970	985	991	1007
M560	655	665	658	657
M565	990	1000	1010	1036
M558	775	790	784	796
M556	575	585	581	581

Figure V-22 presents a plot of the actual furnace temperature versus the potentiometer setting for both preflight calibration and inflight data. The overall result of the difference between the desired and actual soak temperatures achieved with the furnace was considered inconsequential and therefore the MEFS did accomplish its overall objectives.

(2) SL-4 Performance. The MEFS performed as designed. Based on the data obtained during the SL-3 operations, the heat-up time estimates and potentiometer settings were adjusted to provide for better mission planning and system operation. The furnace heat-up times experienced during SL-4 were slightly longer than expected because of lower bus voltage than experienced during SL-3 operation.

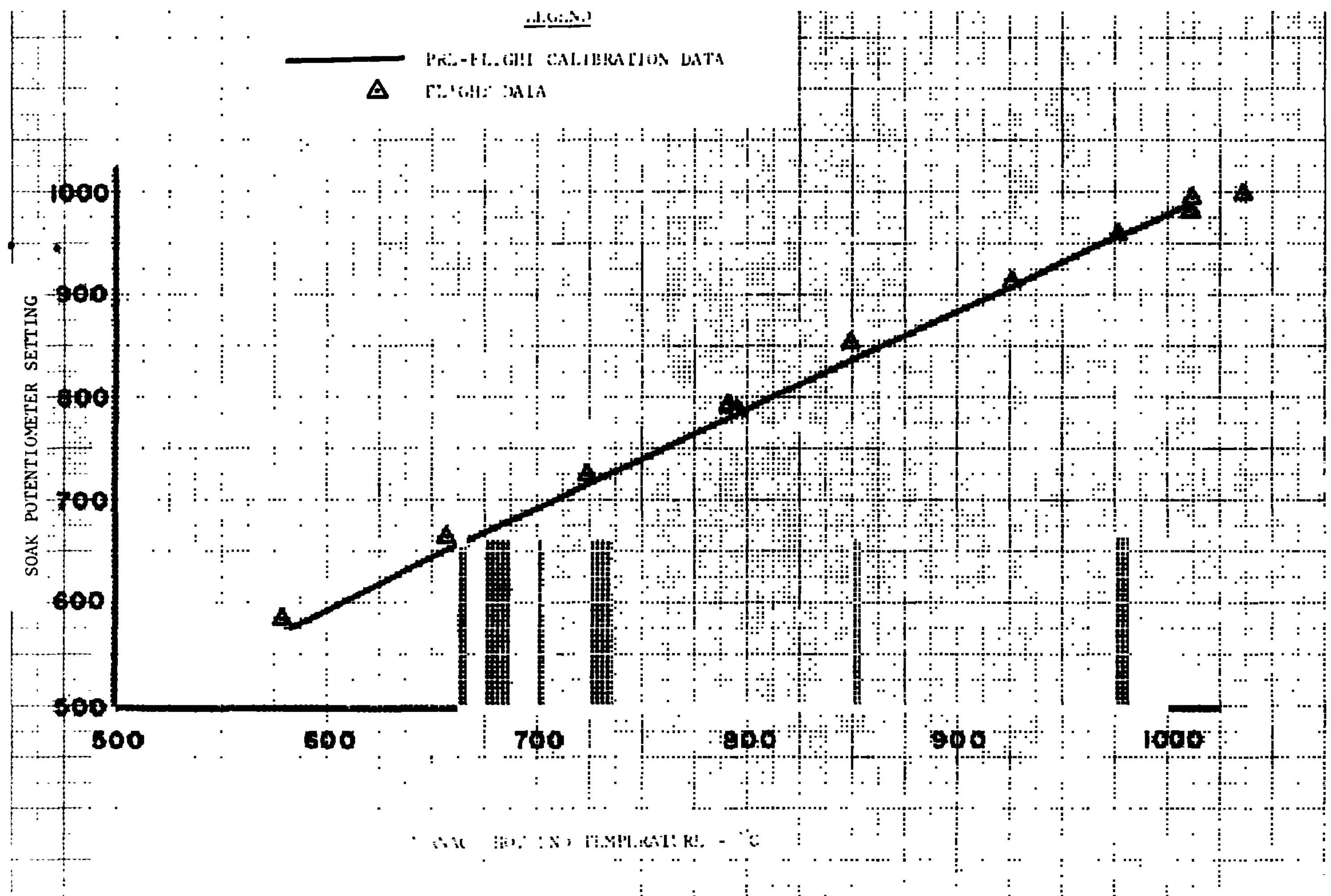


FIGURE V-22. M518 SOAK POTENTIOMETER SETTING VS. ACTUAL FURNACE TEMPERATURE

During SL-4 operation, the AM Bus 1 voltage averaged between 28.4 and 28.6 VDC whereas the bus voltage during SL-3 was between 28.6 and 28.7 VDC. The following table presents the expected and actual heat-up times for each experiment in order of performance.

Experiment \ Heat-Up Time (Hours)	Preflight Estimate	Actual
M557	4.8	5.3
M560	1.3	1.4
M561	3.3	4.5
M563	4.0	5.5
M566	3.0	3.3
M562	2.0	2.2
M556	1.5	1.5

The slightly longer heat-up times had no effect on experiment performance.

The potentiometer data is presented in the following table.

Experiment	Soak Temp Setting	Desired Soak Temp (°C)	Actual Soak Temp (°C)
M557	730	725	726
M560	665	651	650
M561	975	991	991
M563	990	1010	1011
M566	870	860	865
M562	805/665	804/650	803/655
M556	465	450	460

As seen by the data, the adjustments made to the potentiometer settings, using the data from SL-3, provided very accurate settings to obtain the desired soak temperatures.

e. System Interfaces. The system interfaces performed satisfactorily during the mission.

f. Return Data. The physical data returned from the SL-3 mission were the 33 experiment cartridges (eleven experiments, three cartridges each) and from the SL-4 mission, the 21 experiment cartridges (seven experiments, three cartridges each). Each PI was given his experiment samples for evaluation. In addition to the physical data, the following data was obtained and provided to the PIs and the experiment system developer:

Measurement No.	Measurement	Sample Rate
C0055 - 807	Furnace temperature, heat leveler	2 samples/min
C0056 - 807	Furnace temperature, heat extraction plate	"
M0155 - 513	Voltage, AM Bus 1	"
C0018 - 807	MDA temperature, atmospheric gas 1	"
K0382 - 702	ATM digital computer word	"
PHD1X	X-Axis rate gyro 1 reading	"
PHD1Y	Y-Axis rate gyro 1 reading	"
PHD1Z	Z-Axis rate gyro 1 reading	"
PHD2X	X-Axis rate gyro 2 reading	"
PHD2Y	Y-Axis rate gyro 2 reading	
PHD2Z	Z-Axis rate gyro 2 reading	"
PHD3X	X-Axis rate gyro 3 reading	"
PHD3Y	Y-Axis rate gyro 3 reading	"
PHD3Z	Z-Axis rate gyro 3 reading	"
K7030 - 404	TACS thruster I-IV, on	Event
K7031 - 404	" " I-P, "	"
K7032 - 404	" " I-II, "	"
K7033 - 404	" " III-II "	"
K7034 - 404	" " III-P, "	"
K7035 - 404	" " III-IV,"	"

Copies of the crew voice transcripts and experiment debriefing transcripts were also obtained.

g. Anomalies. There were no anomalies affecting the MEFS performance.

2. Experiment M556 - Vapor Growth of IV-VI Compounds. The Principal Investigator for Experiment M556 is Dr. Heribert Wiedemeier, Rensselaer Polytechnic Institute, Troy, New York. The Hardware Developer was Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objectives. The objective was to determine the degree of improvement that can be obtained in the perfection and chemical homogeneity of crystals grown by chemical vapor transport under weightless conditions.

(2) Description. Mixed crystals of compound semiconductor germanium selenide (GeSe) and germanium telluride (GeTe) were grown by chemical transport through a temperature gradient in a transport agent (iodine vapor) from polycrystalline sources of the two component materials. The growth process was performed in sealed quartz ampoules contained in metal cartridges in the M518 Multipurpose Furnace System.

b. Experiment Operation.

(1) SL-3 Operation. The experiment was successfully performed from DOY 263, 1005 GMT through DOY 265, approximately 0700 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (°C)	585	581	581	575
Soak Period (Hours)	32	32	33.2	64
Cool-Down Rate (°C/Min)	Passive	Passive	Passive	Passive

A time-temperature profile for the experiment is shown in figure V-23.

(2) SL-4 Operation. Experiment M556 was successfully performed from DOY 006, 2010 GMT through DOY 009, 0116 GMT. The following table indicates a comparison of flight data with expected results and M518 control package settings.

	Control Package Setting	Desired Results	Actual Results
Soak Temperature (°C)	465	450	460
Soak Period (Hours)	32	32	33.1
Cool-Down Rate (°C/Min)	Passive	Passive	Passive

Figure V-24 is a time-temperature profile for the experiment performance on SL-4.

3. <u>Experiment M557 - Immiscible Alloy Compositions</u>. The Principal Investigator for Experiment M557 is Mr. Jo L. Reger, TRW Systems Group, Redondo Beach, California. The experiment hardware was developed by the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to determine the effects of near-zero-g on the processing of material compositions which normally segregate on earth.

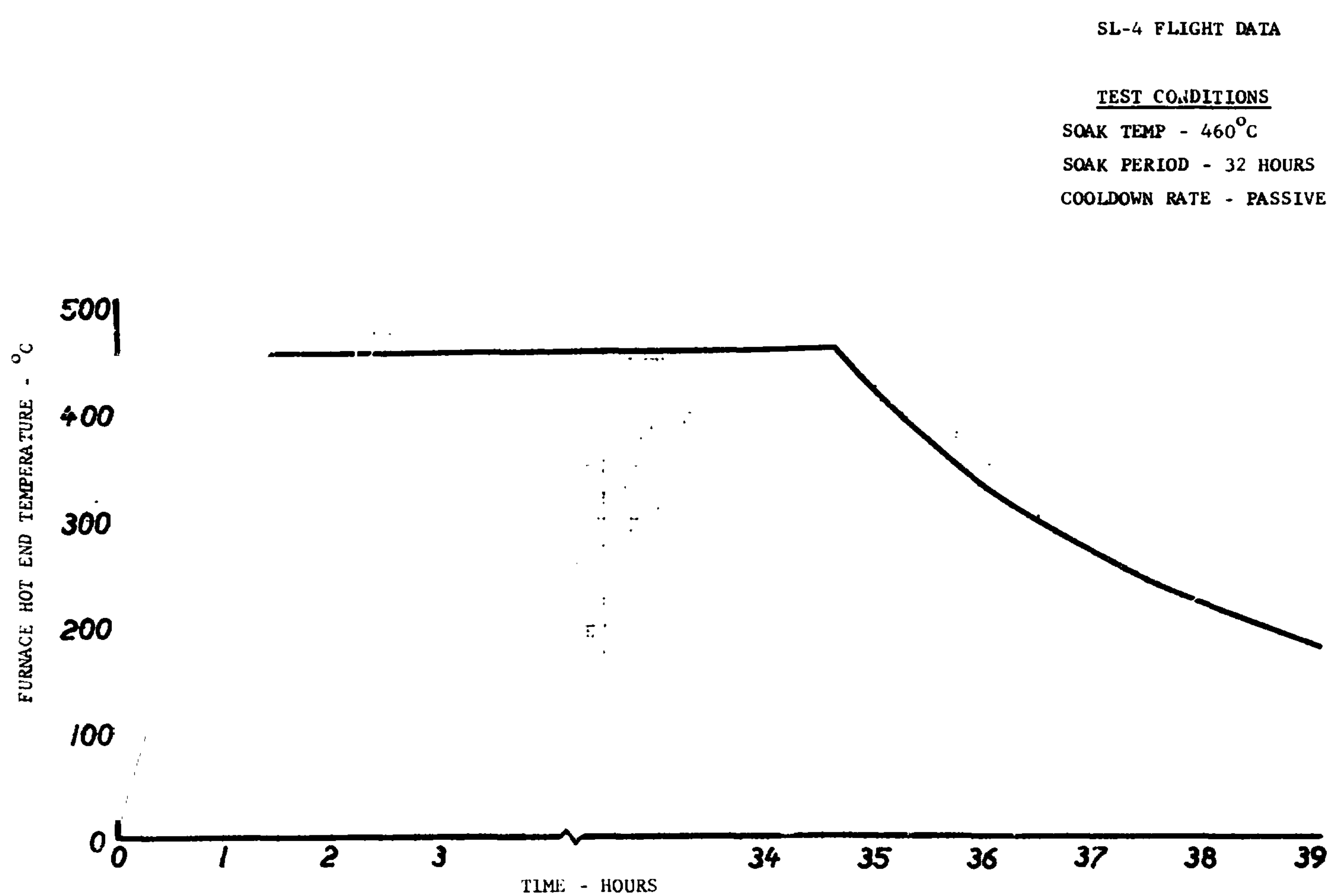


FIGURE V-23. M556 TIME - TEMPERATURE PROFILE (SL-3)

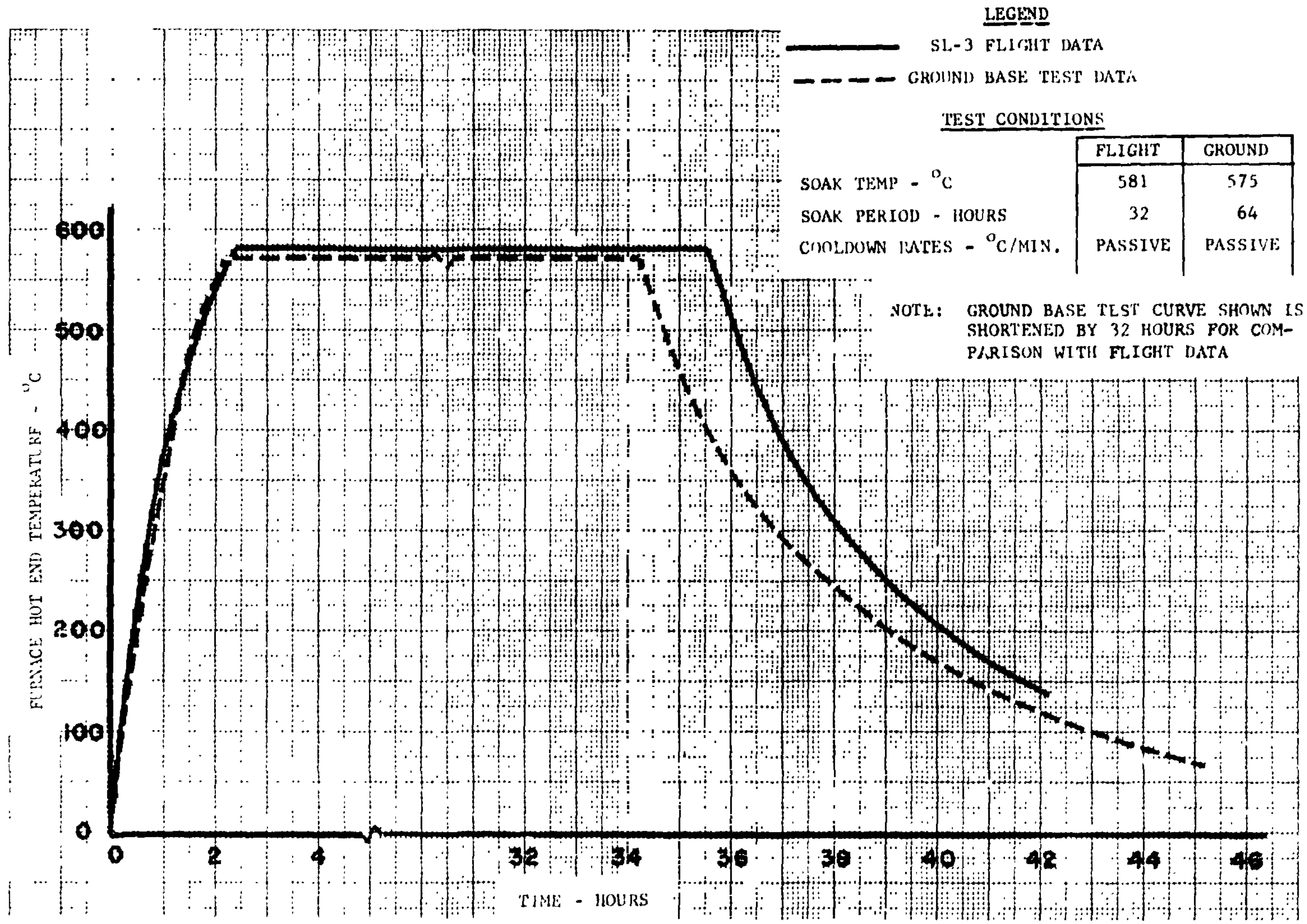


FIGURE V-24. M556 TIME - TEMPERATURE PROFILE (SL-4)

(2) Description. The experiment consisted of three sample materials:

Ampoule A Isothermal solidification of 45-45-10 percent by weight lead-zinc-antimony (Pb-Zn-Sb) ternary couple which exhibits both liquid and solid state immiscibility.

Ampoule B - Isothermal solidification of a 76.8-23.2 percent by weight of gold-germanium (Au-Ge) binary couple which exhibits essentially complete immiscibility in the solid state.

Ampoule C - Directional solidification of a 70-15-15 percent by weight lead-indium-tin (Pb-In-Sn) ternary couple which exhibits limited solubility in the solid state.

Each of the three couples was individually packaged, ampoules A and B in stainless steel and ampoule C in quartz-tubing. Each M557 cartridge contained an ampoule of each type and was processed in the M518 Multipurpose Furnace System.

b. Experiment Operation

(1) SL-3 Operation. The experiment was successfully performed from DOY 251, 2105 GMT through DOY 252, 2250 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (°C)	725	732	724	720
Soak Period (Hours)	4	4	4.1	3.9
Cool-Down Rate (°C/Min)	Passive	Passive	Passive	Passive

A time-temperature profile for the experiment is shown in figure V-25.

(2) SL-4 Operation. The experiment was successfully performed from DOY 355, 1900 GMT through DOY 357, 2040 GMT. The following table indicates a comparison of flight data with expected results and M518 control package settings.

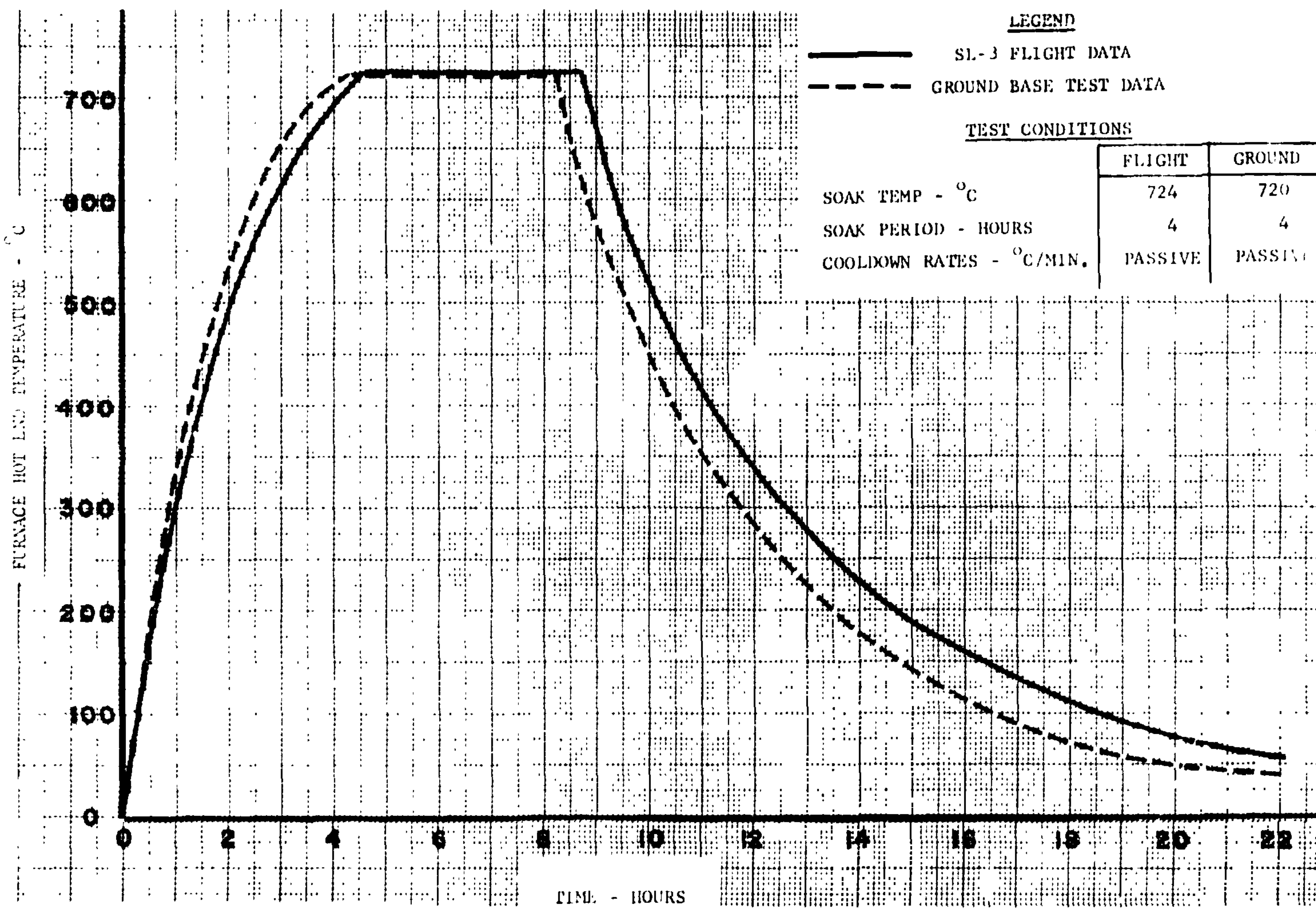


FIGURE V-25. M557 TIME - TEMPERATURE PROFILE (SL-3)

	Control Package Settings	Desired Results	Actual Results
Soak Temperature (^{o}C)	730	725	726
Soak Period (Hours)	4	4	4
Cool-Down Rate (^{o}C/Min)	Passive	Passive	Passive

Figure V-26 is a time-temperature profile for the experiment performance on SL-4.

4. Experiment M558 - Radioactive Tracer Diffusion. The Principal Investigator for Experiment M558 is Dr. Anthony O. Ukanwa, Howard University, Washington, D.C. The experiment hardware was developed by the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to measure self-diffusion and impurity diffusion effects in liquid metals in space flight and to characterize the disturbing effects, if any, due to spacecraft acceleration.

(2) Description. Three zinc metal rods were prepared with a section of radioactive zinc (Zn-65) plated to one end of each of two rods and in the midsection of the third rod. The zinc rods, which were encased in tantalum and sealed in cartridges, were melted in the M518 Multipurpose Furnace System, held at a constant temperature while the radioactive atoms diffused into the liquid metal, and then allowed to solidify.

b. Experiment Operation. The experiment was successfully performed on the SL-3 mission from DOY 262, 1640 GMT through DOY 263, 0930 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	790	784	796	775
Soak Period (Hours)	1	1	0.9	1
Cool-Down Rate (^{o}C/Min)	Passive	Passive	Passive	Passive

A time-temperature profile for the experiment is shown in figure V-27.

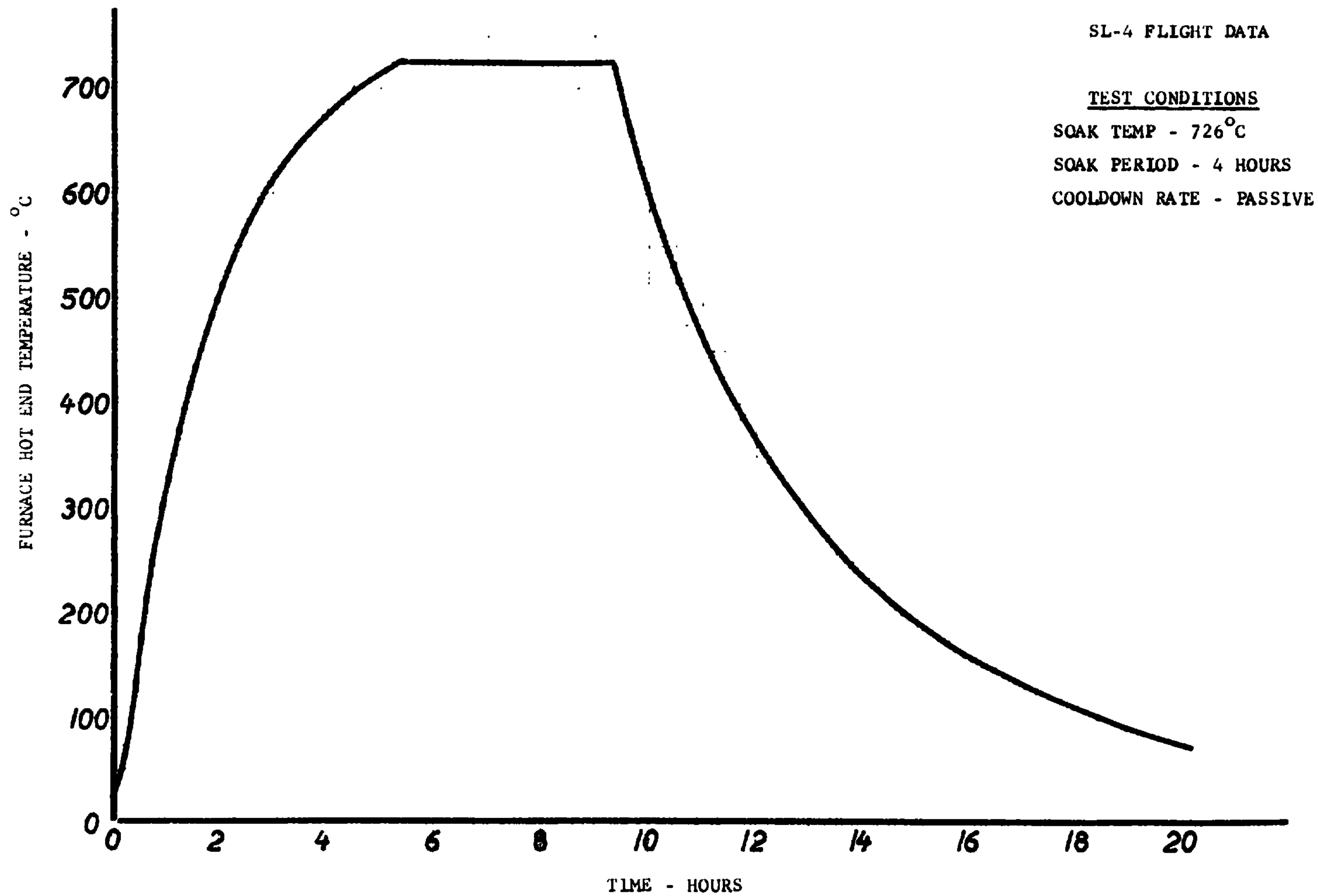


FIGURE V-26. M557 TIME - TEMPERATURE PROFILE (SL-4)

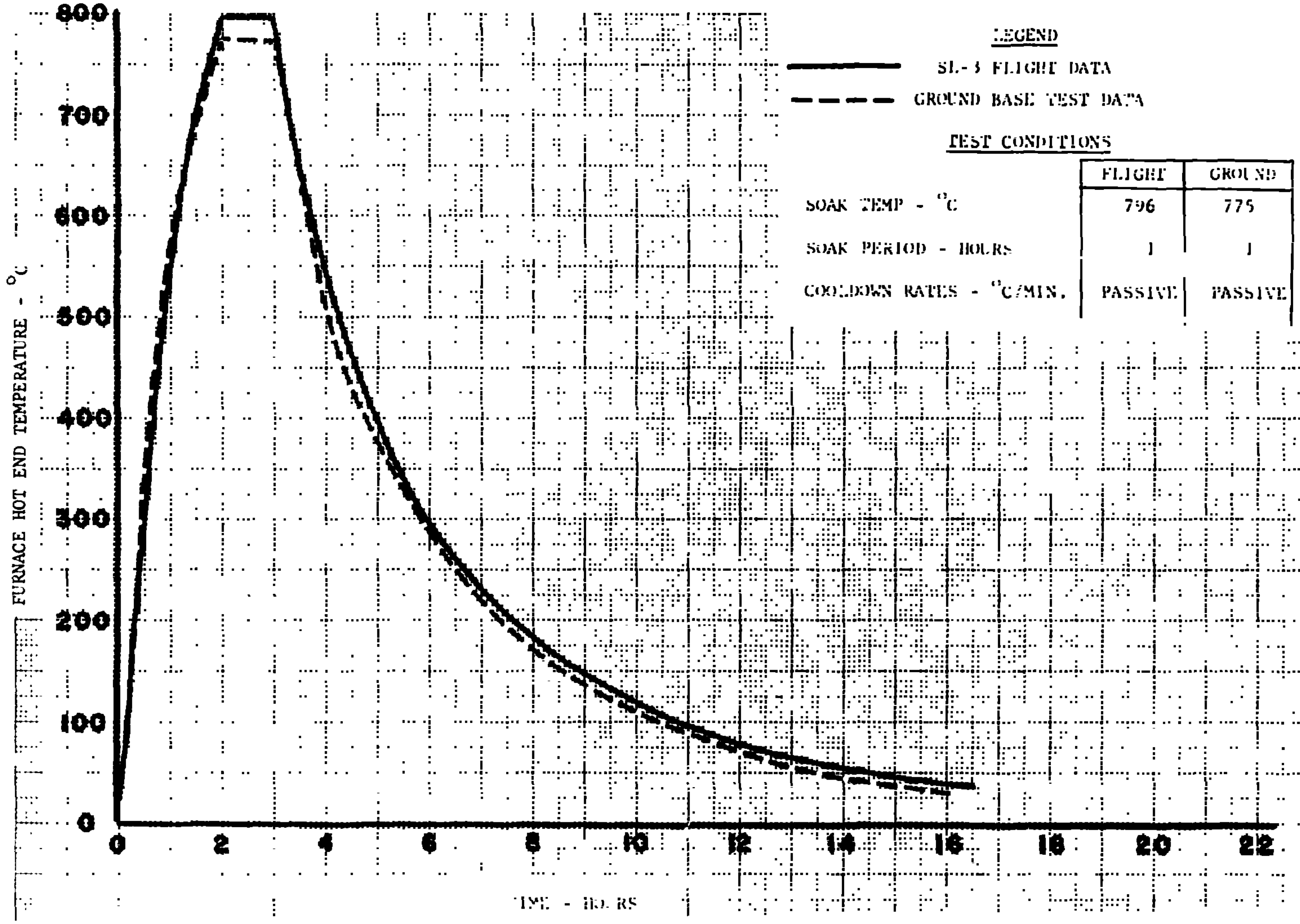


FIGURE V-27. M558 TIME - TEMPERATURE PROFILE (SL-3)

5. Experiment M559 - Microsegregation in Germanium. The Principal Investigators for Experiment M559 are Drs. F. Voltmer and J. Yue, Texas Instruments, Inc., Dallas, Texas. The experiment hardware was developed by the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to determine the degree of microsegregation of doping impurities in germanium caused by convectionless directional solidification under conditions of weightlessness and to determine whether the low-g environment materially influenced the homogeneity of the impurity distribution.

(2) Description. Single-crystal rods of germanium doped with antimony (an electron donor, N-type), gallium and boron (electron acceptors, P-type) were placed in cartridges, positioned so that one end of each rod extended into the M518 furnace hot zone. When the furnace was heated, only the part of each rod within the hot zone melted, leaving a solid part to serve as a seed for regrowth of the crystal when the melt resolidified. The rods were directionally solidified at the slowest available cooling rate to promote formation of single crystals.

b. Experiment Operation. The experiment was successfully performed on the SL-3 mission from DOY 256, 2055 GMT through DOY [illegible]8, 0110 GMT. The following table indicates a comparison of flight data and data obtained for ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	995	1005	1012	95[illegible]
Soak Period (Hours)	2	2	2.3	2.1
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6	0.6

A time-temperature profile for the experiment is shown in figure V-28.

6. Experiment M560 - Growth of Spherical Crystals. The Principal Investigator for Experiment M560 is Dr. Hans U. Walter, University of Alabama, Huntsville, Alabama. The experiment hardware was developed by the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

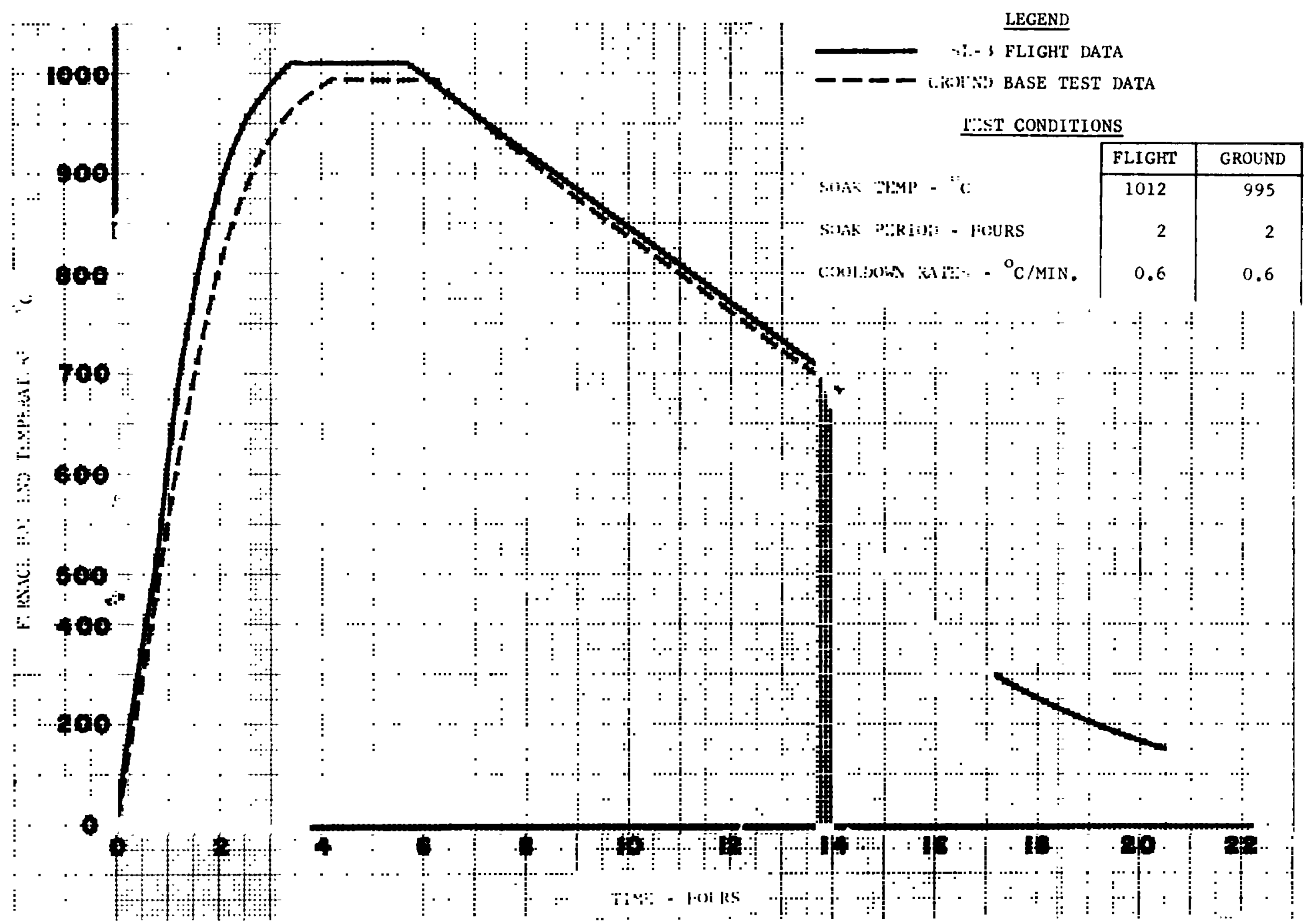


FIGURE V-28. M559 TIME - TEMPERATURE PROFILE (SL-3)

a. Description

(1) Objective. The objective was to grow doped indium antimonide (InSb) crystals of high chemical homogeneity and structural perfection and study their resulting physical properties in comparison with theoretical values for ideal crystals.

(2) Concept. Prepared samples of indium antimonide, encased in cartridges, were melted in the M518 Multipurpose Furnace to produce suspended drops of molten material attached to solid seed crystals. The drops were solidified by removing heat through the seed crystals while heat losses from the surfaces of the liquid drops was compensated. In this manner the crystalline material in contact with the seed grows inside the drop with the liquid on the drop surface being the last to solidify, thus eliminating mechanical strain due to volume change on solidifying.

b. Experiment Operation

(1) SL-3 Operation. The experiment was successfully performed from DOY 260, 2100 GMT through DOY 261, 1743 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	665	658	657	636
Soak Period (Hours)	1	1	1	1
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6	0.6

A time-temperature profile for the M560 experiment is shown in figure V-29.

(2) SL-4 Operation. The experiment was successfully performed from DOY 361, 0015 GMT through DOY 261, 2245 GMT. The following table indicates a comparison of flight data with expected results and M518 control package settings.

	Control Package Setting	Desired Results	Actual Results
Soak Temperature (^{o}C)	665	651	650
Soak Period (Hours)	1	1	1.1
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6

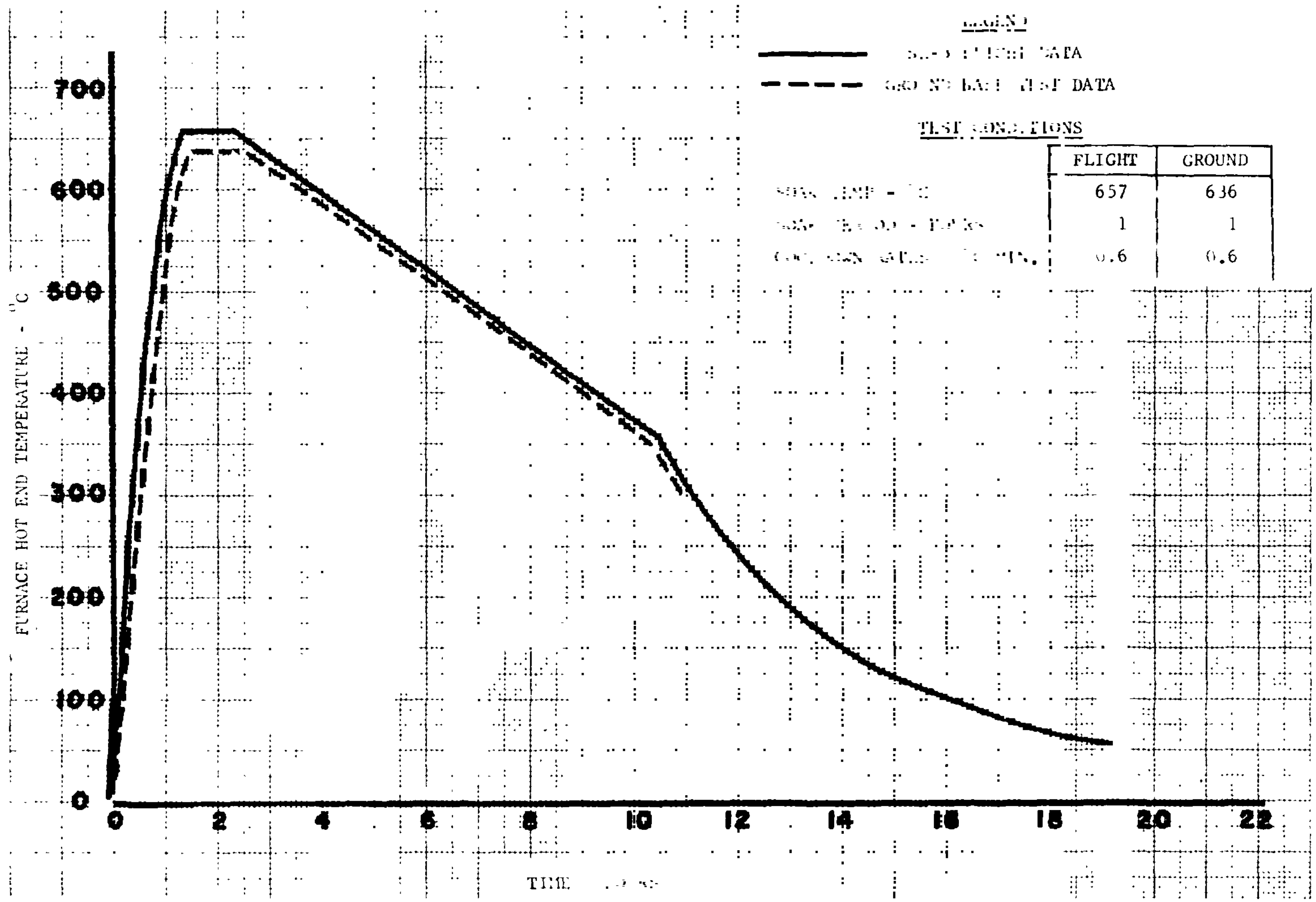


FIGURE V-29. M560 TIME - TEMPERATURE PROFILE (SL-3)

Figure V-30 is a time-temperature profile for the experiment performance on SL-4.

7. Experiment M561 - Whisker-Reinforced Composites. The Principal Investigator for Experiment M561 is Dr. Tomoyoshi Kawada, Director, National Research Institute for Metals, Tokyo, Japan. The Hardware Developer was Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to produce void-free samples of silver, reinforced with oriented silicon carbide whiskers.

(2) Description. Sintered compacts of silver containing distributions of unidirectionally-oriented silicon carbide whiskers (1 micron diameter by 1 mm long) were melted in the M518 Multipurpose Furnace. Pressure, from a spring actuated piston, was used to force voids from the melt and to promote wetting of the whiskers by the matrix material.

b. Experiment Operation.

(1) SL-3 Operation. The experiment was successfully performed from DOY 259, 2020 GMT, through DOY 260, 1800 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	985	991	1007	980
Soak Period (Hours)	4	4	3.7	1
Cool-Down Rate (^{o}C/Min)	Passive	Passive	Passive	Passive

A time-temperature profile for the experiment is shown in figure V-31.

(2) SL-4 Operation. The experiment was successfully performed from DOY 362, 0225 GMT, through DOY 363, 1420 GMT. The following table indicates a comparison of flight data with expected results and M518 control package settings.

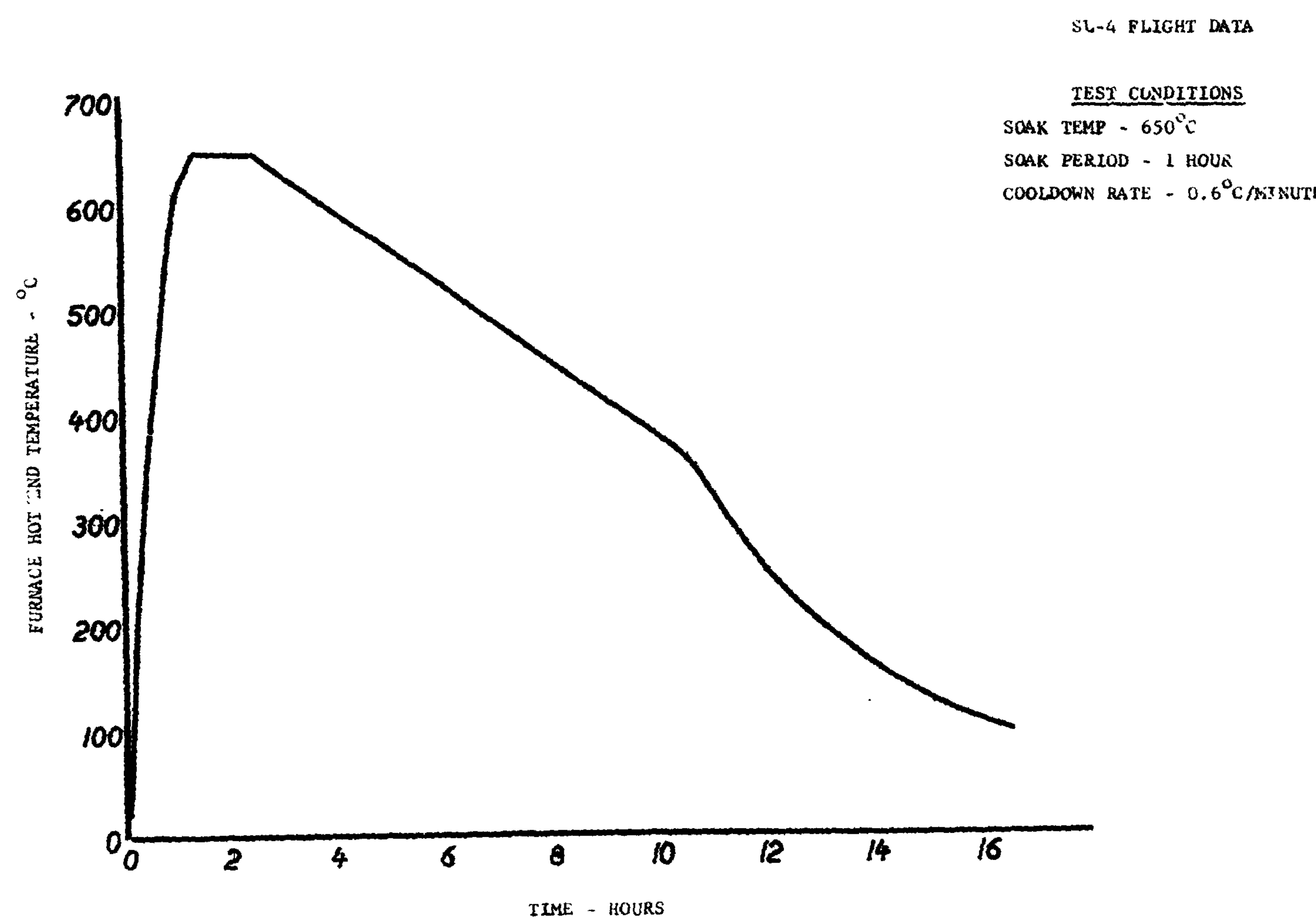


FIGURE V-30. M560 TIME - TEMPERATURE PROFILE (SL-4)

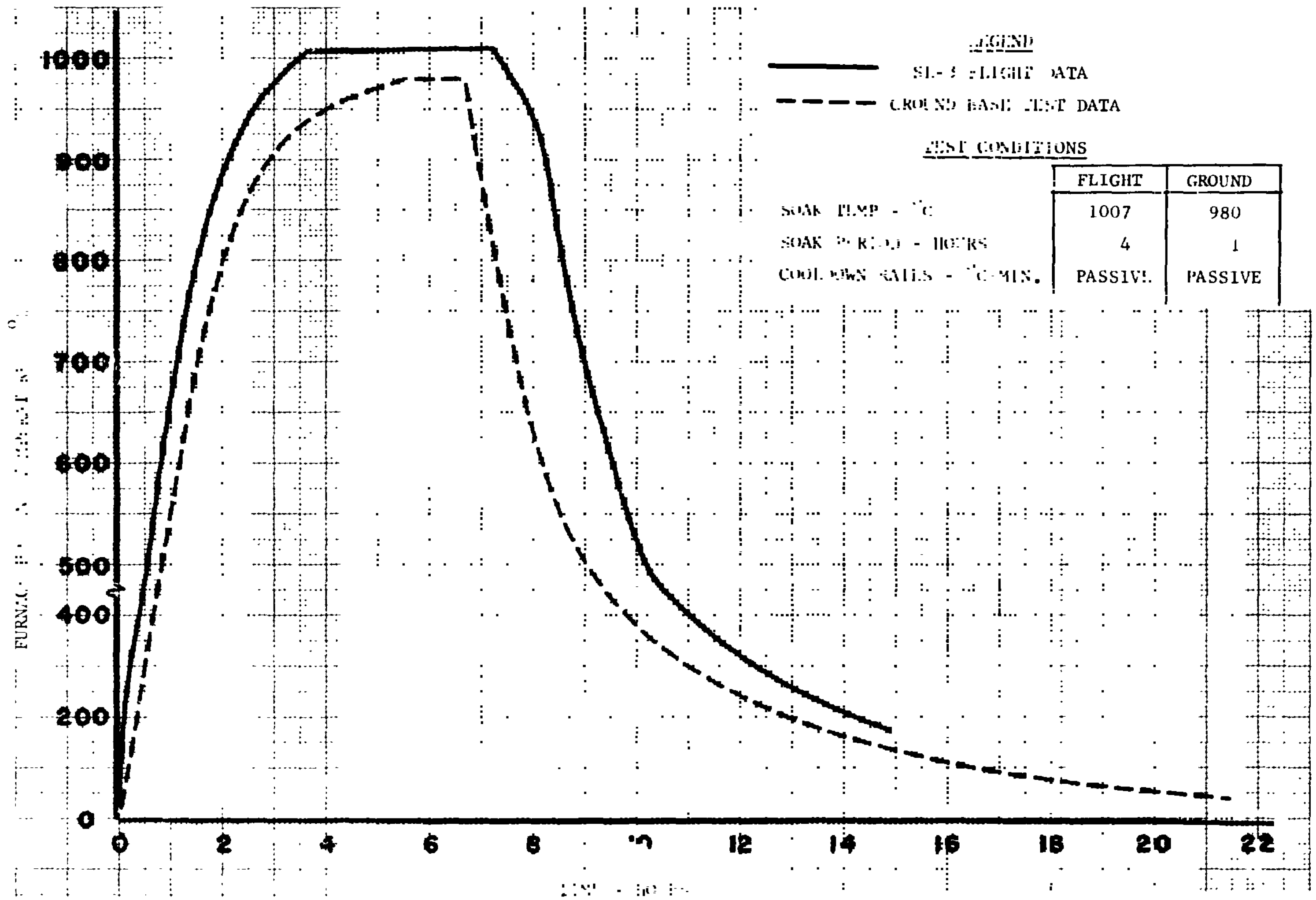


FIGURE V-31. M561 TIME - TEMPERATURE PROFILE (SL-3)

	Control Package Setting	Desired Results	Actual Results
Soak Temperature (^{o}C)	975	991	991
Soak Period (Hours)	1	1	1
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6

Figure V-32 is a time-temperature profile for the experiment performance on SL-4.

8. Experiment M562 - Indium Antimonide Crystals. The Principal Investigators for Experiment M562 are Drs. Harry C. Gatos and August Witt, Massachusetts Institute of Technology, Cambridge, Massachusetts. The Hardware Developer was the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description

(1) Objective. The objective was to produce doped semiconductor crystals of high chemical homogeneity and structural perfection and to evaluate the influence of weightlessness in attaining these properties.

(2) Description. High-quality single crystals of indium antimonide (InSb) were prepared in the laboratory, doped with tellurium, precision machined and etched to fit into heavy wall quartz ampoules, sealed, and enclosed in metal cartridges. Half of each crystal (about three inches in length) was melted in the M518 furnace and regrown at a rate of 1.3 cm (0.5 inches) per hour using the unmelted half as a seed.

b. Experiment Operation.

(1) SL-3 Operation. The experiment was successfully performed from DOY 253, 1300 GMT through DOY 254, 1600 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	795	804	792	800
Soak Period (Hours)	1	1	0.9	0.9
Cool-Down Rate (^{o}C/Min)	1.2	1.2	1.2	1.2

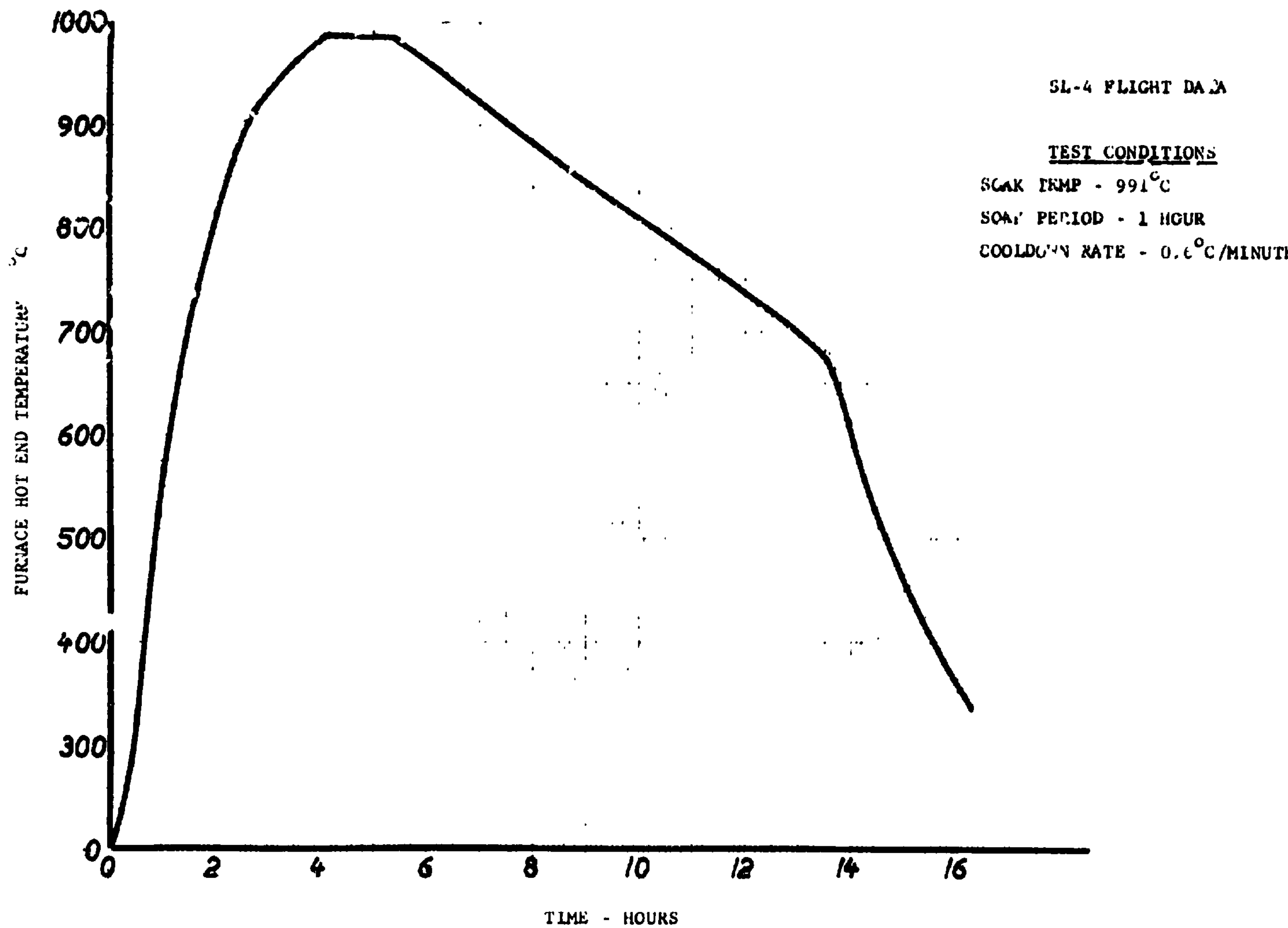


FIGURE V-32. M561 TIME - TEMPERATURE PROFILE (SL-4)

A time-temperature profile for the experiment is shown in figure V-33.

(2) SL-4 Operation. Experiment M562 was successfully performed from DOY 005, 1515 GMT through DOY 006, 1350 GMT. The PI requested two unique requirements for the performance on SL-4. First, the M512 work chamber was physically hit approximately two hours after the start of controlled cool-down to apply a known-time disturbance during the resolidification process to assist in ground analysis of the crystals. Second, at approximately three hours after the start of controlled cool-down, the M518 control package was reconfigured to provide a second soak period (at approximately 650°C) for one hour. The following table indicates a comparison of flight data with expected results and M518 control package settings.

	Control Package Settings	Desired Results	Actual Results
Soak Temperature (°C)	805/665	804/650	803/655
Soak Period (Hours)	1/1	1/1	1/1
Cool-Down Rate (°C/Min)	1.2/Passive	1.2/Passive	1.2/Passive

9. Experiment M563 - Mixed III-V Crystal Growth. The Principal Investigator for Experiment M563 is Dr. William R. Wilcox, University of Southern California, Los Angeles, California. The Hardware Developer was the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to determine how weightlessness affects directional solidification of binary semiconductor alloys and, if single crystals were obtained, to determine how their semiconducting properties depended on alloy composition.

(2) Description. Alloys of indium antimonide (InSb) and gallium antimonide (GaSb) in proportions of In.1 to Ga.9, In.3 to Ga.7 and In.5 to Ga.5 were placed in separate fused silica ampoules, encased in cartridges, melted in the M518 Multipurpose Furnace, and directionally solidified at the slowest available rate.

b. Experiment Operation.

(1) SL-3 Operation. The experiment was successfully performed from DOY 258, 0200 GMT through DOY 259, 2000 GMT. The following table indicates a comparison of flight data and data obtained

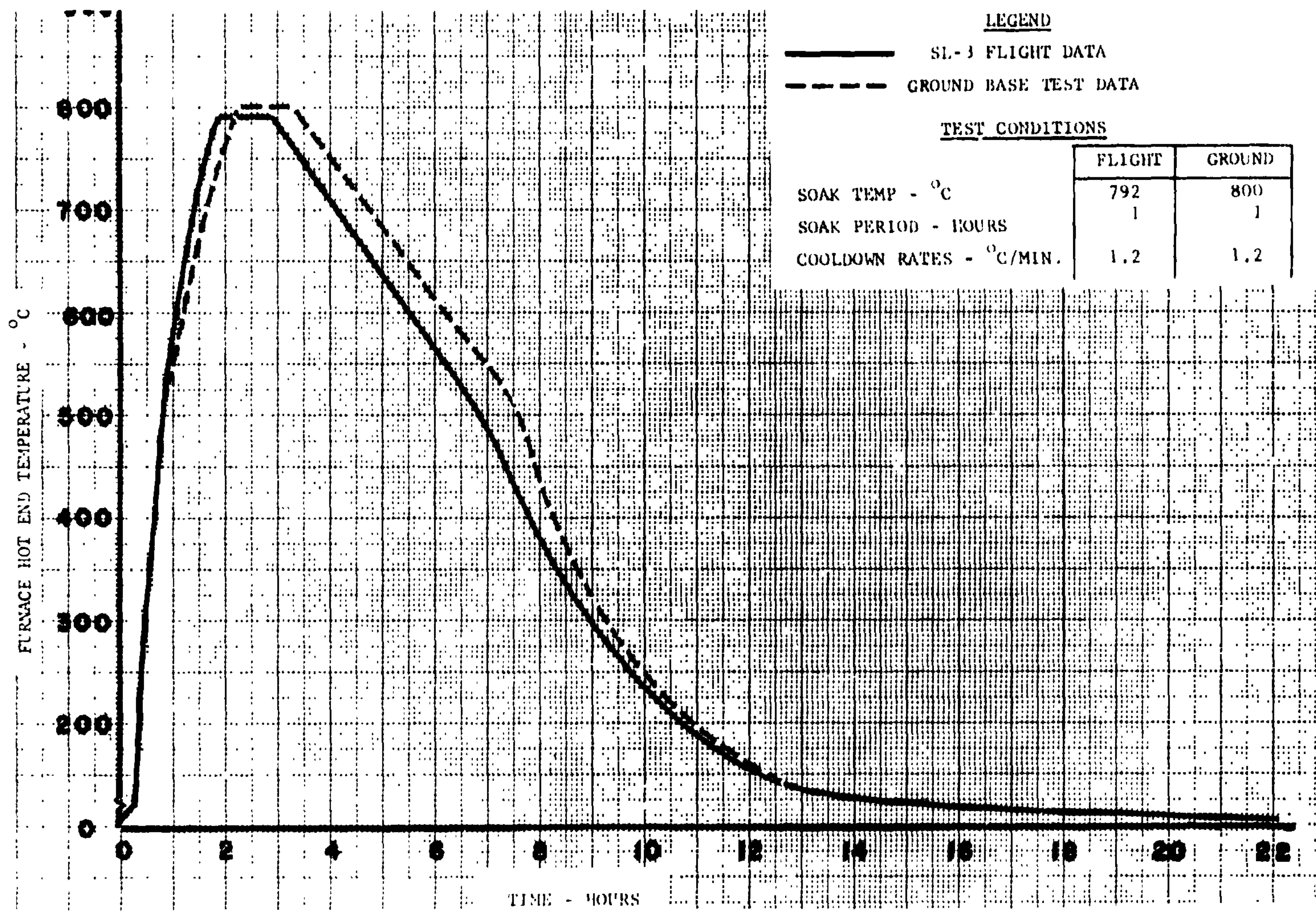


FIGURE V-33. M562 TIME - TEMPERATURE PROFILE (SL-3)

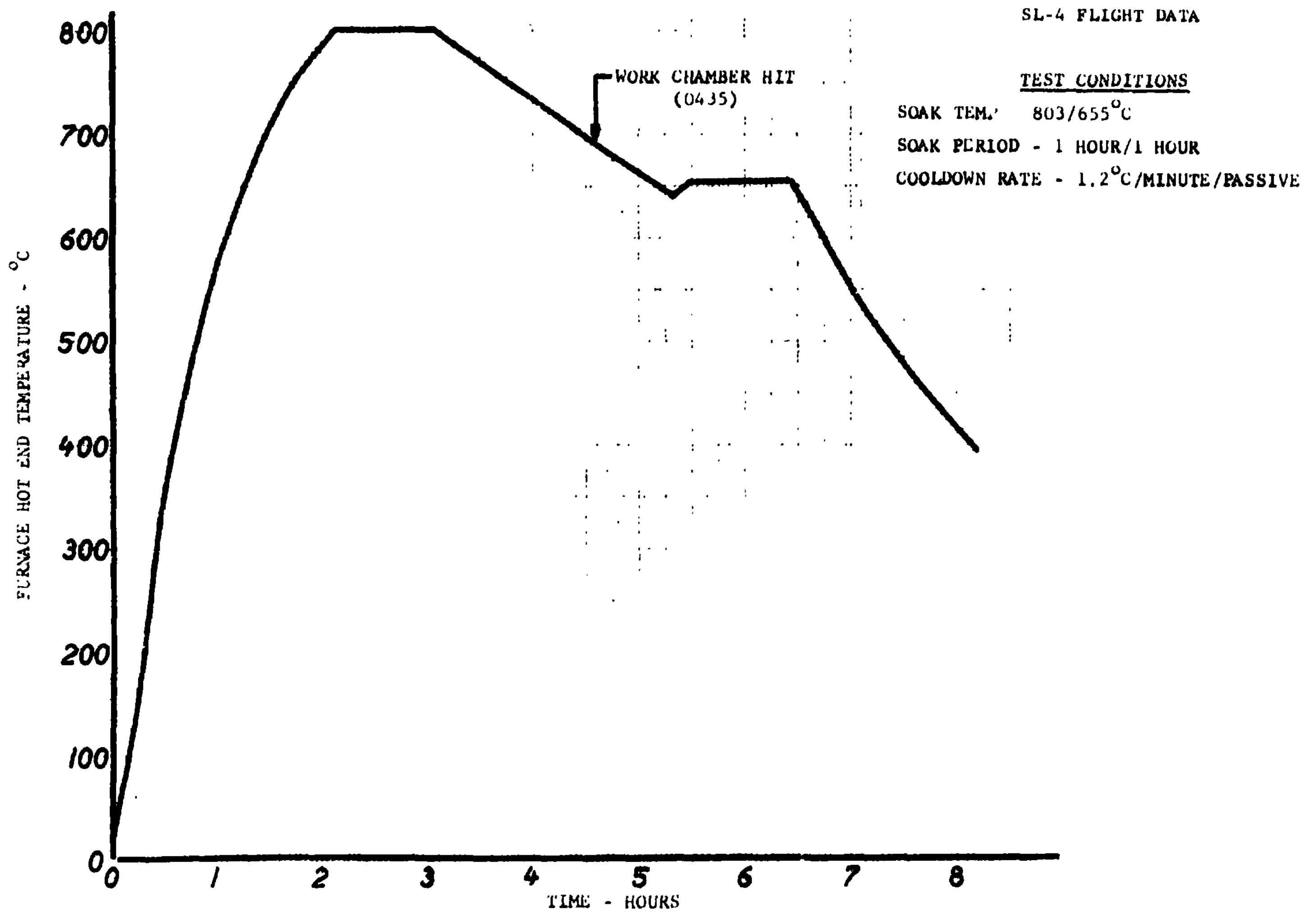


FIGURE V-34. M562 TIME - TEMPERATURE PROFILE (SL-4)

from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	960	966	976	960
Soak Period (Hours)	16	16	16.3	15
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6	0.6

A time-temperature profile for the M563 experiment is shown in figure V-35.

(2) SL-4 Operation. The experiment was successfully performed from DOY 364, 0335 GMT through DOY 001, 0000 GMT. The following table indicates a comparison of flight data with expected results and M518 control package settings.

	Control Package Settings	Desired Results	Actual Results
Soak Temperature (^{o}C)	990	1010	1011
Soak Period (Hours)	16	16	16.3
Cool-Down Rate (^{o}C/Min)	0.6	0.6	0.6

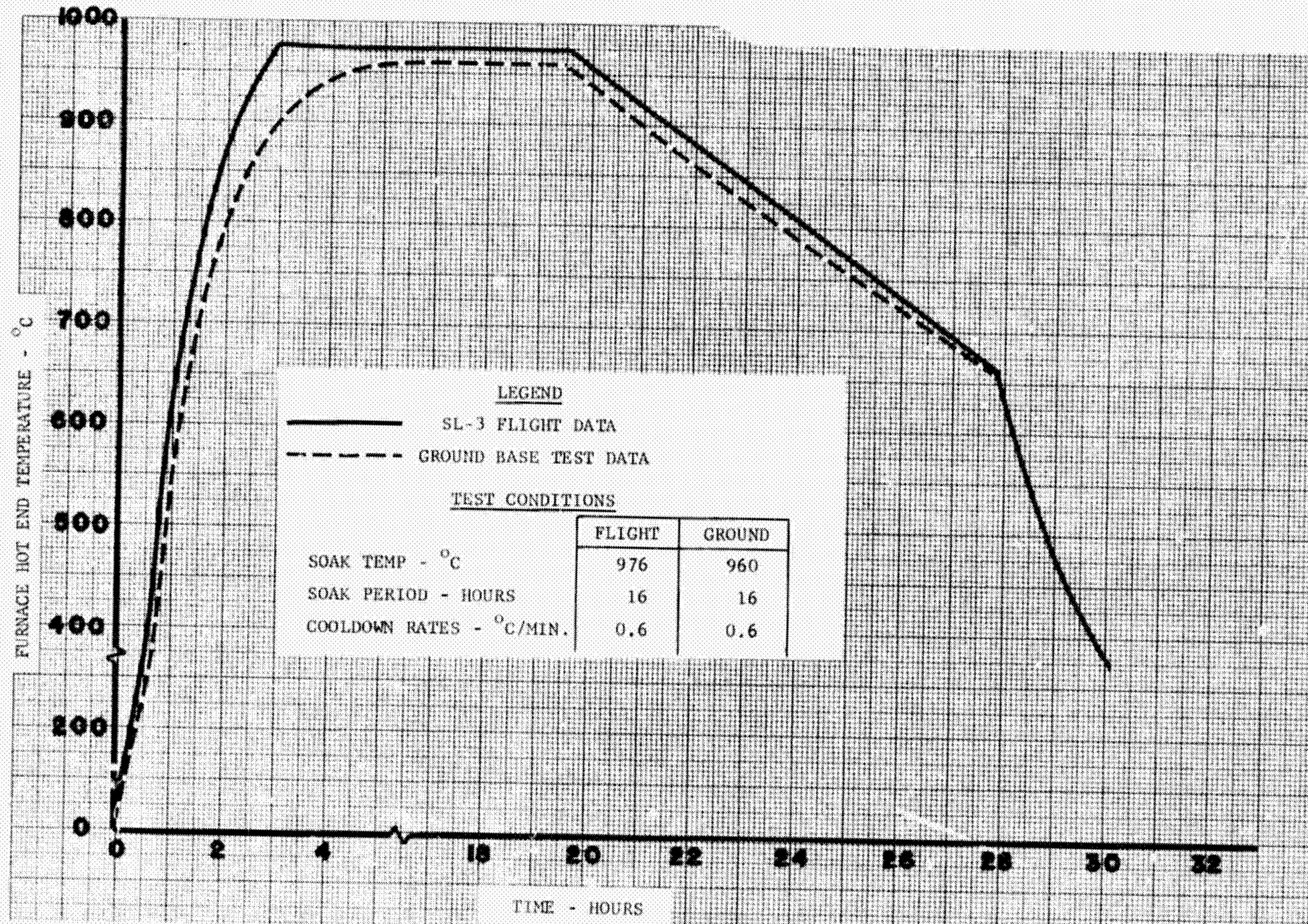
Figure V-36 is a time-temperature profile for the experiment performance on SL-4.

10. Experiment M564 - Halide Eutectics. The Principal Investigator for Experiment M564 is Dr. Alfred S. Yue, University of California, Los Angeles, California. The Hardware Developer was the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to produce highly continuous controlled structures in samples of fiberlike sodium fluoride-sodium chloride (NaF-NaCl) eutectic, and to measure their physical properties.

(2) Description. Three ingots of the eutectic, 1.3 cm (½ inch) in diameter and 10.2 cm (4 inches) long, were grown in the M518 Multipurpose Furnace by melting the alloys and then cooling them directionally at the slowest available rate.



	FLIGHT	GROUND
SOAK TEMP - ^{o}C	976	960
SOAK PERIOD - HOURS	16	16
COOLDOWN RATES - ^{o}C/MIN.	0.6	0.6

FIGURE V-35. M563 TIME - TEMPERATURE PROFILE (SL-3)

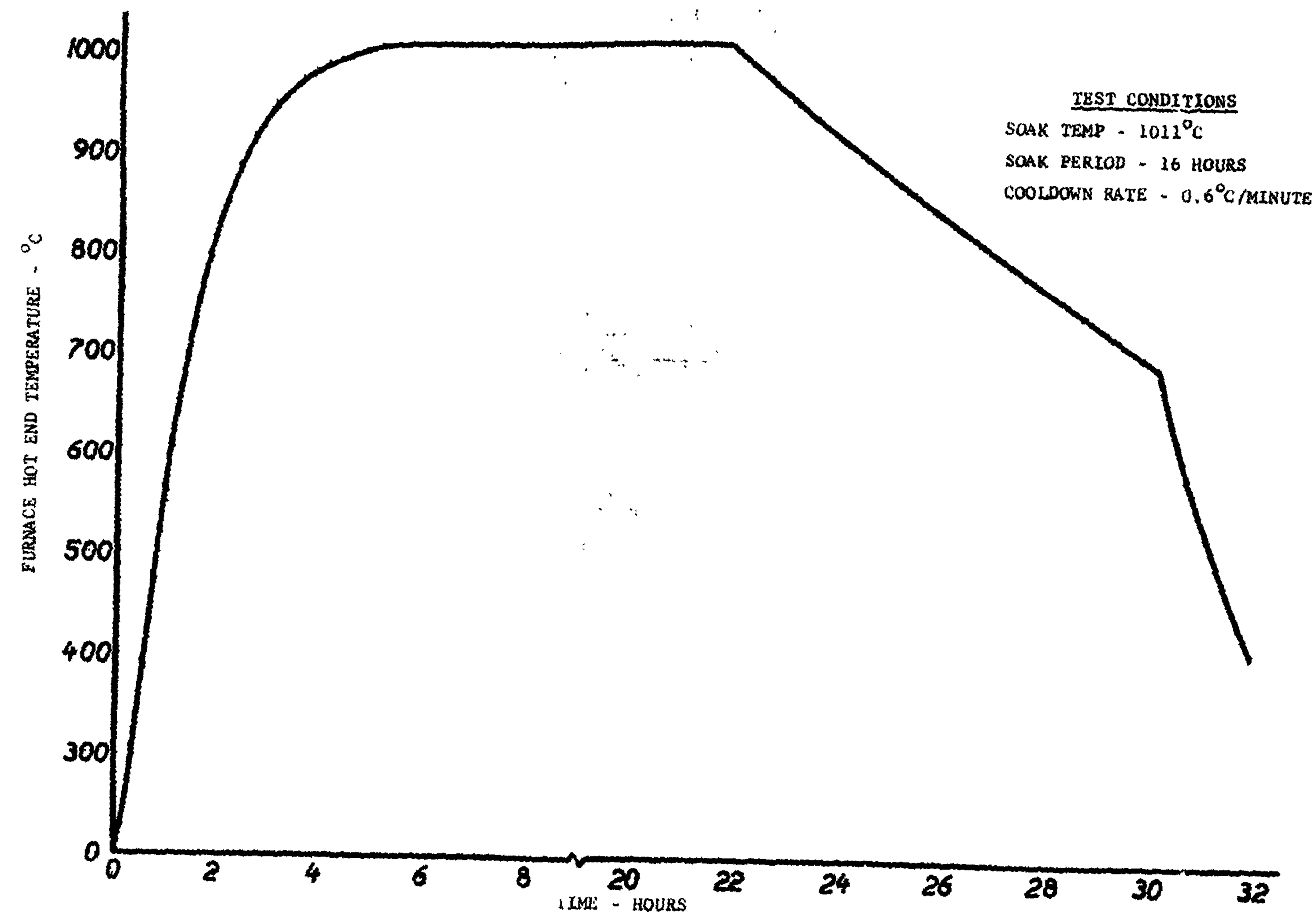


FIGURE V-36. M563 TIME - TEMPERATURE PROFILE (SL-4)

b. Experiment Operation. The experiment was successfully performed on the SL-3 mission from DOY 255, 1450 GMT through DOY 256, 2022 GMT. The following table indicates a comparison of the flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (°C)	915	911	926	900
Soak Period (Hours)	1	1	1	1
Cool-Down Rate (°C/Min)	0.6	0.6	0.6	0.6

A time-temperature profile for the experiment is shown in figure V-37.

11. Experiment M565 - Silver Grids Melted in Space. The Principal Investigator for Experiment M565 is Dr. A. Deruyttere, Katholieke Universiteit Leuven, Heverlee, Belgium. The Hardware Developer was Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to determine how pore sizes and pore shapes changed in porous structures when melted and resolidified in space.

(2) Description. The experiment consisted of three different ampoules:

Ampoule A - Eight silver discs of 14 mm diameter and 0.1 mm thick in which one or more holes had been spark cut or drilled as follows, when counting from the hot end of the ampoule.

P8: One central hexagonal hole of 3.5 mm sides
P7: One central hexagonal hole of 3.5 mm sides
P6: One central square hole of 3.5 mm sides
P5: Four square holes of 1 mm sides and 6.4 mm apart
P4: Nine round holes of 1 mm diameter and 3.2 mm apart
P3: 21 round holes of 1 mm diameter and 1.6 mm apart
P2: 14 round holes of 2 mm diameter and 0.8 mm apart
P1: 21 round holes of 2 mm diameter and 0.4 mm apart

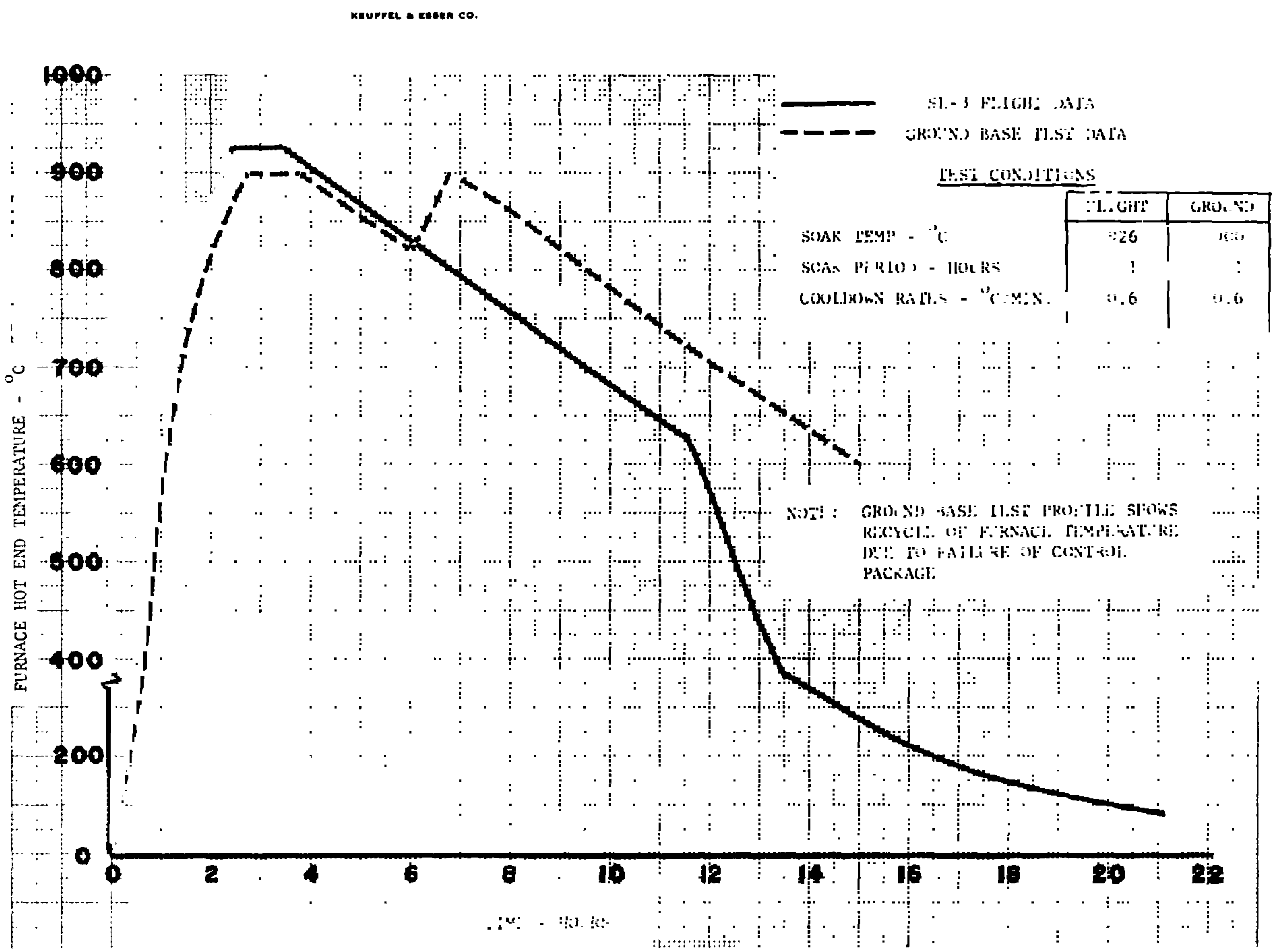


FIGURE V-37. M564 TIME - TEMPERATURE PROFILE (SL-3)

Ampoule B - Same as Ampoule A except disc thickness was 0.5 mm

Ampoule C - Single sample of silver fibers of 0.4 mm diameter and 10-15 mm long, compressed and sintered to form a prism of 40 mm x 14 mm x 4 mm with a porosity of 30%

Each of the ampoule contents was packaged in silica ampoules, encased in stainless steel cartridges and processed in the M518 Multipurpose Furnace System.

b. Experiment Operation. The experiment was successfully performed on the SL-3 mission from DOY 261, 1807 GMT through DOY 262, 1523 GMT. The following table indicates a comparison of flight data with data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (°C)	1000	1010	1036	960/1000
Soak Period (Minutes)	60	60	60	5/10
Cool-Down Rate (°C/Min)	Passive	Passive	Passive	Passive

A time-temperature profile for the M565 experiment is shown in figure V-38.

12. Experiment M566 - Aluminum-Copper Eutectic. The Principal Investigator for Experiment M566 is Mr. Earl A. Hasemeyer, Process Engineering Laboratory, Huntsville, Alabama. The Hardware Developer was the Westinghouse Astronuclear Laboratory, Large, Pennsylvania.

a. Description.

(1) Objective. The objective was to determine the effects of weightlessness on the solidification of lamellar structure in a eutectic alloy when directionally solidified.

(2) Description. Three 0.6 cm (¼ inch) rods of super purity aluminum - 33% copper alloy (Al-$CuAl_2$ eutectic alloy) in individual cartridges were partially melted and then directionally solidified in the M518 Multipurpose Furnace using a linear temperature gradient of 45° C/cm minimum.

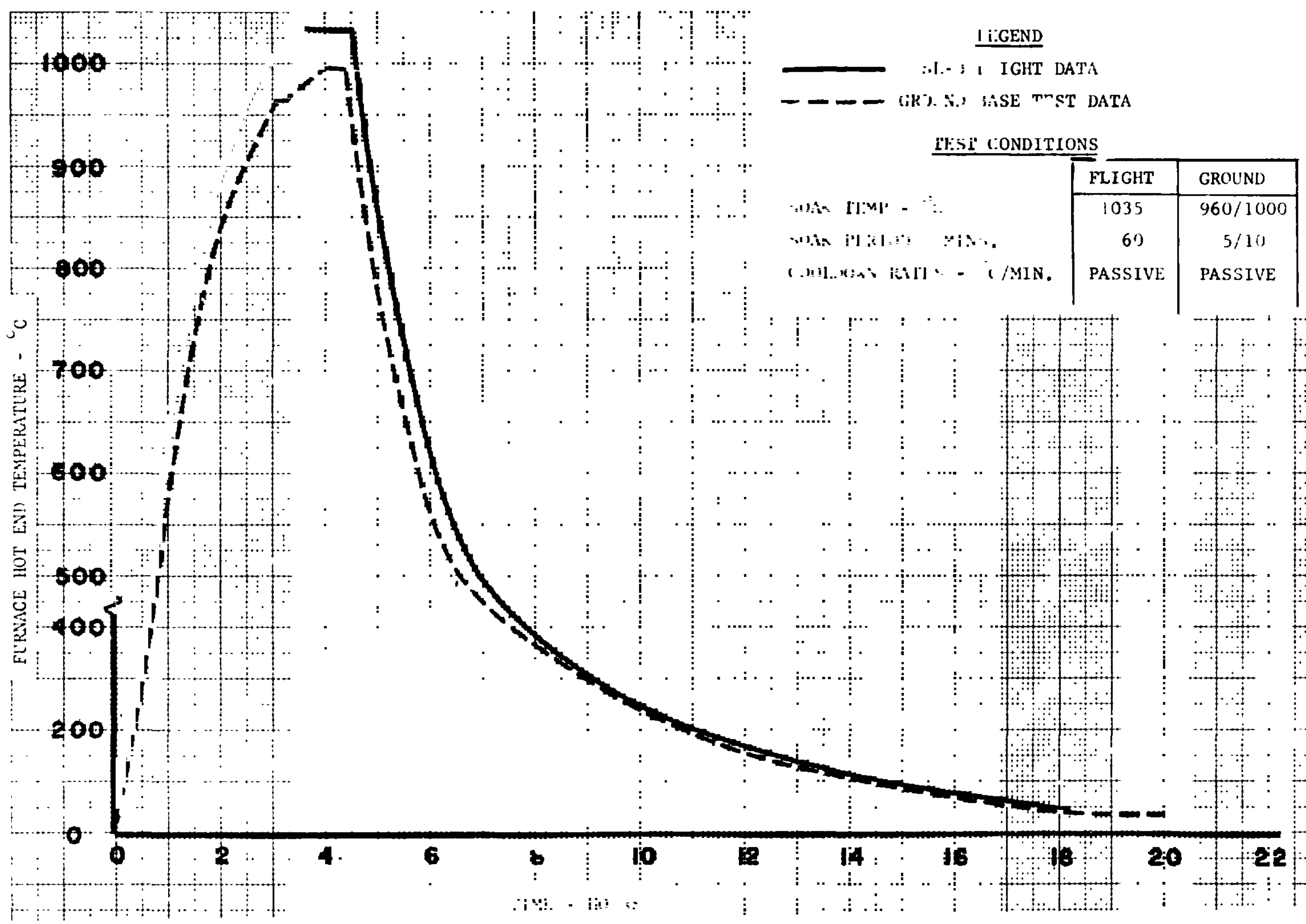


FIGURE V-38. M565 TIME - TEMPERATURE PROFILE (SL-3)

b. Experiment Operation.

(1) SL-3 Operation. The experiment was successfully performed from DOY 254, 1625 GMT through DOY 255, 1420 GMT. The following table indicates a comparison of flight data and data obtained from ground testing for the experiment as well as the M518 control package settings.

	Control Package Setting	Desired Results	Actual Results	Ground Test Results
Soak Temperature (^{o}C)	855	867	849	860
Soak Period (Hours)	1	1	1	1
Cool-Down Rate (^{o}C/Min)	2.4	2.4	2.4	2.4

A time-temperature profile for the experiment is shown in figure V-39.

(2) SL-4 Operation. The experiment was successfully performed from DOY 004, 1525 GMT through DOY 005, 1240 GMT. During the performance on SL-4, the PI requested that approximately the first hour of controlled cool-down be when the Skylab orientation was Z-LV. This request was made to determine differences in resolidifcation patterns between the Z-LV attitude and solar inertial attitude. In Z-LV, the sample would remain at the same altitude all around the earth whereas in solar inertial there is a small cyclical variation at the sample location in the spacecraft. The following table indicates a comparison of flight data with expected results and M518 control package settings.

	Control Package Settings	Desired Results	Actual Results
Soak Temperature (^{o}C)	870	860	865
Soak Period (Hours)	1	1	1.1
Cool-Down Rate (^{o}C/Min)	2.4	2.4	2.4

Figure V-40 is a time-temperature profile for the experiment performance on SL-4.

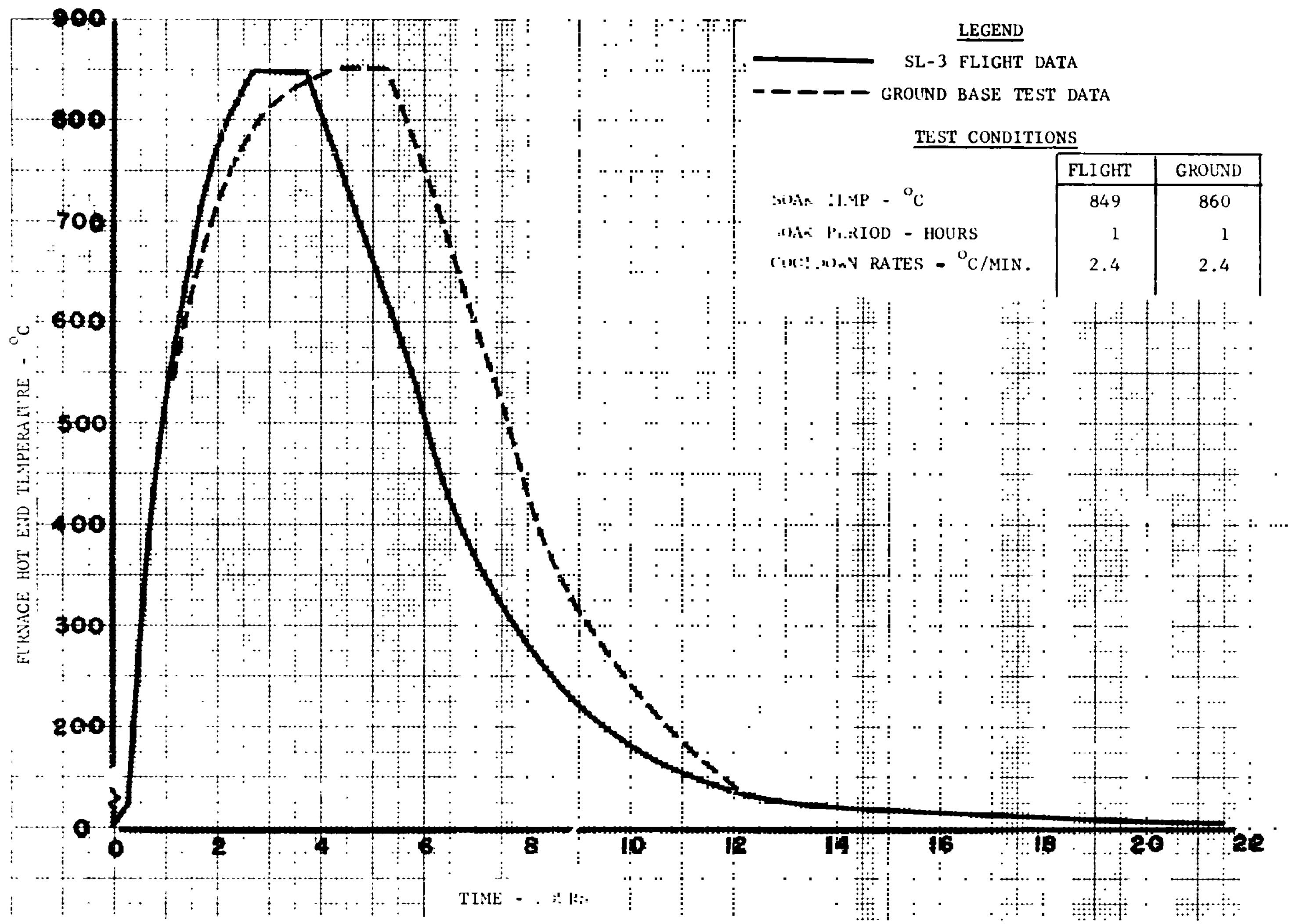


FIGURE V-39. M566 TIME - TEMPERATURE PROFILE (SL-3)

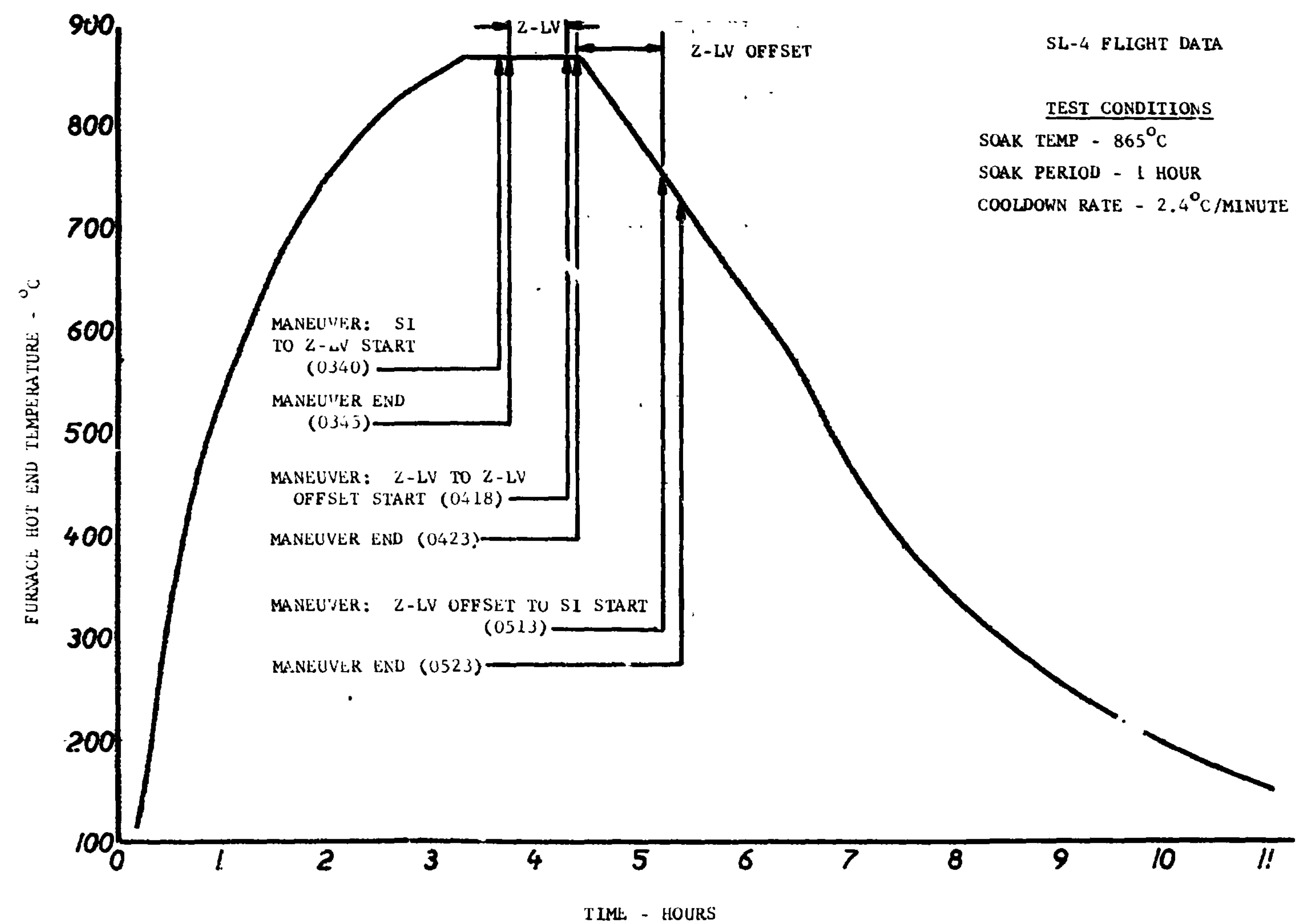


FIGURE V-40. M566 TIME - TEMPERATURE PROFILE (SL-4)

SECTION VI. STUDENT EXPERIMENTS

A. Experiment ED31-Bacteria and Spores

The Student Investigator for Experiment ED31 is Robert L. Staehle, Harley School, Rochester, New York. He was assisted by a NASA Science Advisor. The hardware was developed and built by MSFC.

1. Experiment Description. Results of previous spaceflights led to the hypothesis that microbial simplification (the loss of complete species of micro-organisms, and changes in characteristics such as growth rate, form, structure, coloring and texture) occurs in closed ecological environments.

a. Objective. The objective was to determine the effects of internal Skylab environment (particularly weightlessness) on the survival, growth rates and mutations of vegetative bacterial forms in a closed ecological cycle.

b. Concept. Several bacterial species were to be exposed to the Skylab environment, periodically photographed, and returned for comparison with identical control groups which were to be subjected to a normal laboratory environment.

c. Hardware Description. The basic experiment hardware was commercial equipment. Specifically developed hardware included an experiment container, a plastic bag, a petri dish container, and a photographic bracket assembly. Experiment equipment and functions are listed in table VI-1. Supporting equipment and functions are listed in table VI-2. The hardware is shown in figure VI-1.

2. Experiment Operation. This experiment was originally planned for performance during the last seven mission days of SL-2. The petri dishes were to be innoculated with three strains of the pure bacteria species. Nine of the fifteen dishes were to be incubated in the inflight medical support system (IMSS) incubator at a nominal 35°C (95°F) and the remaining six petri dishes were to be incubated at OWS ambient temperature. Periodic photographs were to be made of each petri dish according to the schedule of table VI-3.

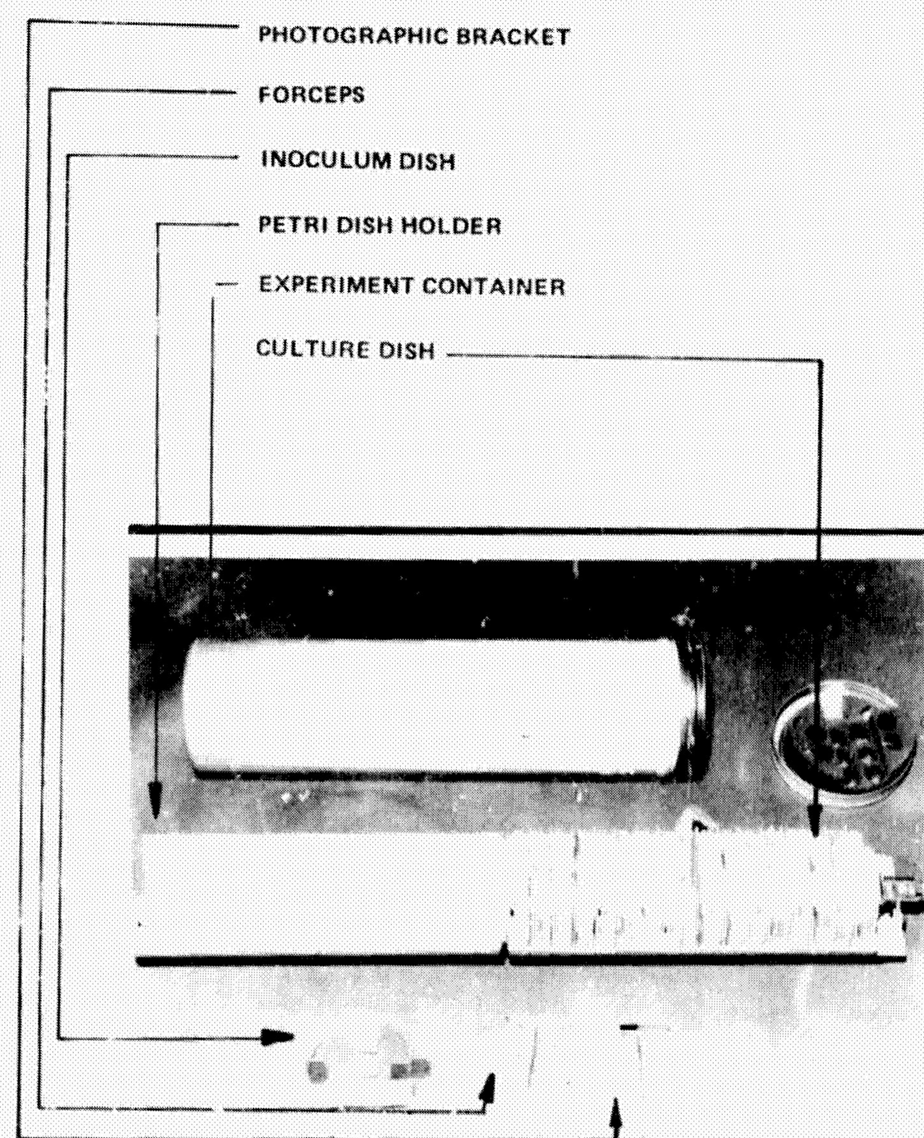
Immediately following the final photographic sequence the petri dishes were to be placed in the IMSS re-supply container and stowed in the food chiller to inhibit further bacterial growth. Transfer to the CM for earth return was to take place as late in the mission as feasible to maintain the desired chill temperature of 5°C ± 3°C until receipt at the laboratory for analysis.

TABLE VI-1. ED31 EXPERIMENT EQUIPMENT

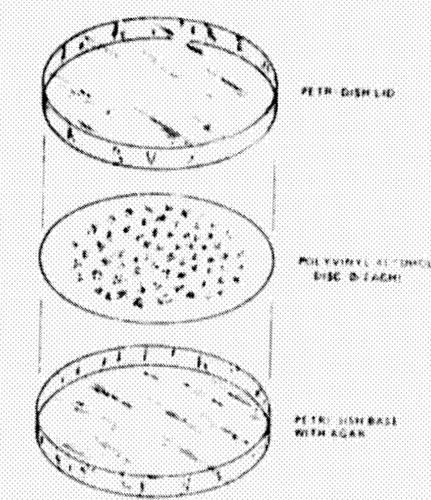
Experiment Equipment	Function
Experiment container	To protect the contents of the petri dish container during launch and storage at 5 psi
Plastic bag	To preserve sterility of petri dish holder and contents
Petri dish container	To restrain dishes and facilitate removal and insertion of dishes in container
Petri dishes with media (15)	To house the selected bacteria during incubation, growth, and return
Inoculum petri dish (1)	To contain inoculum during pre-flight storage, launch and in-flight storage
Sterile forceps (2 pairs)	For handling of inoculum
Photographic bracket assy	To hold petri dishes for photography

TABLE VI-2. ED31 SUPPORTING EQUIPMENT

Supporting Equipment	Function
Nikon F 35mm camera	To photograph bacterial growth
55mm lens for Nikon F camera (Visible, f 2.8 1/125 sec)	Standard camera lens
Lens adapter (Nikon E-2)	To permit close-up photography
35mm film cassette Film type S0168	Photographic--film supply
OWS film vault	Film stowage
IMSS resupply container	To stow petri dishes for return
Return canister	Hold petri dishes for return to earth
OWS food chiller	To inhibit bacterial growth during post-operational stowage
Log Book	To record data of inflight experiment progress
Power cable (IMSS)	To supply power to IMSS incubator
IMSS incubator	Incubation of petri dishes
Scissors	To open plastic bag



VIEW OF HARDWARE



PETRI DISH DETAILS

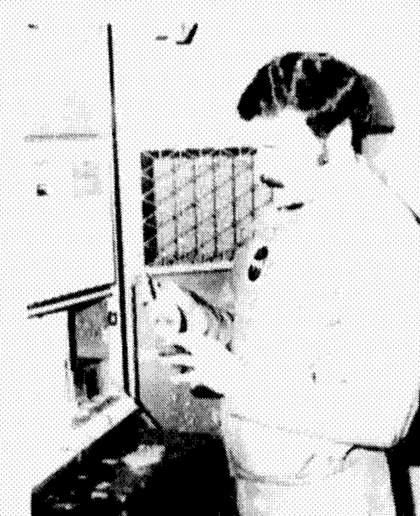


FIGURE VI-1. ED31 EXPERIMENT EQUIPMENT

TABLE VI-3 PHOTOGRAPHIC SCHEDULE

Operation	Elapsed Time (Hrs)
Preparation	0
Operation 1	12 $\pm$ 2
Operation 2	24 $\pm$ 2
Operation 3	36 $\pm$ 4
Operation 4	48 $\pm$ 4

a. SL-2 Operations. The experiment results were compromised by:

Decreased bacterial viability due to:

Abnormally high temperatures resulting from the OWS meteoroid shield loss.

The 10-day delay between SL-1 and SL-2 launch.

The deletion of the IMSS resupply module from SL-2 stowage for the experiment return.

Potential data loss resulting from short supply of 35 mm S0168 film requiring a reduction from 75 to 50 frames of film data.

These factors caused much concern for the actual ED31 operation. The experiment was removed from the scheduled experiments list and placed on a contingency shopping list.

ED31 was initiated on DOY 166 at 0030 GMT. The SPT, Dr. Kerwin, innoculated the petri dishes, and placed nine in the IMSS incubator at 29°C (84°F) and the remaining six in the OWS for ambient incubation.

The photographic schedule was modified due to the SPT's comment on the very slow growth rate.

Deletion of the IMSS resupply module from stowage resulted in the 15 petri dishes being returned by improvised means. This means used an IMSS heat sink and chilled wash cloths as insulating material in a food overcan. The overcan was taped to a second chilled overcan (containing blood samples) and the two cans wrapped in towels. The assembled overcans and towels were tied to a CM locker door exterior.

TABLE VI-4 SL-2 PHOTOGRAPHIC SCHEDULE

Operation	GMT	DOY	Actual Elapsed Time (Hrs Min)	Scheduled Elapsed Time (Hrs)
Preparation	0030	166	No Record of Photography	----
Operation 1	1132	166	1132	12 ± 2
Operation 2	2108	166	1938	24 ± 2
Operation 3	0932	167	3302	36 ± 4
Operation 4	2116	168	6846	48 ± 4
Stow	2126	168	----	----

Examination of the returned petri dishes revealed that from an expected development of 2500 colonies only 75 showed growth. As a consequence of these minimal results, ED31 was re-assigned for re-supply and performance on SL-4.

b. SL-4 Operations. The ED31 prototype hardware was launched on SL-4. The operations were initially scheduled as planned for SL-2 but were rescheduled for earlier performance based on other mission considerations (see 3.b. SL-4).

The preparation took place on DOY 003 at 2030 GMT. The photographic observations proceeded according to the schedule in table VI-5. The extended time for operation 4 was approved since the voice transcript review indicated a slower bacterial colony development time.

The CDR reported at the experiment debriefing that a returned-photograph review indicated a focusing problem with the Nikon 3, E2 camera adapter used for closeup photography. Correlation of the photographs with the returned petri dishes may provide usable data from the out-of-focus photographs.

TABLE VI-5 SL-4 PHOTOGRAPHIC SCHEDULE

Operation	GMT	DOY	Actual Elapsed Time (Hrs Min)	Scheduled Elapsed Time (Hrs)
Preparation	2200	003	0	0
Operation 1	1230	004	1430	12 ± 2
Operation 2	2230	004	2430	24 ± 2
Operation 3	1200	005	3800	36 ± 4
Operation 4	1430	007	8830	48 ± 4
Stow	1500	007	----	----

3. Experiment Constraints. The experiment constraints were successfully met during the mission except:

a. SL-2. The initial photographic observation was not made due to a shortage of 35mm S0168 film.

The apparent slow colony development rate caused the total incubation time to be extended beyond the nominal 48 hours.

b. SL-4. Experiment performance was requested prior to the planned operations during the last 7 mission days. The Science Advisor was induced to make this request because of continuing reports of a shortened mission resulting in a potential deletion of this experiment. These reports resulted from one CMG failure and the impending failure of another.

Again the reported slow development rate of the bacterial colonies resulted in an extension of the incubation period beyond the nominal 48 hours.

4. Hardware Performance. The experiment hardware performed as planned.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission except for the high temperatures experienced during SL-1/SL-2 experiment stowage.

6. <u>Return Data</u>.

a. SL-2. The return data consisted of 15 petri dishes with bacterial colonies and 50 frames of 35mm film.

b. SL-4. The return data consisted of 15 petri dishes with bacterial colonies and 75 frames of 35mm film.

7. <u>Anomalies</u>. No anomalies occurred during hardware performance.

B. Experiment ED32 - In-Vitro Immunology

The Student Investigator for Experiment ED32 was Todd A. Meister, Bronx High School of Science, Jackson Heights, New York. He was assisted by a NASA Science Advisor. The hardware was developed and built by MSFC.

1. Experiment Description. In-vitro immunology is a study of immunity to disease "in glass" as opposed to "in a living organism." The immune system in man functions as a defense against any pathogenic organism introduced into his physiological system. The parameters having potential effects on man's immune response include radiation, oxygen enriched environments and prolonged exposure to weightlessness.

a. Objective. The objective was to determine the effects of the Skylab internal environment on the antigen-antibody reaction in-vitro, a fundamental immune response mechanism.

b. Concept. A precipitin reaction (radical immunodiffusion) was to be observed under spacecraft conditions using human antigen reacting against a specific antibody suspended in agar. In this technique, the antigen is to be injected into and allowed to diffuse through the antibody-filled agar. A precipitate will form wherever concentrations of both antigen and antibody are optimum. This precipitate appears as a cloudy white ring surrounding the point at which the antigen was introduced. The diameter of the ring is a direct function of the concentration of the antigen and antibody.

The results were to be observed and photographed periodically. Comparison of the zero-g antigen-antibody sample photographs with identical one-g controls run on the ground will lead to the determination of any changes induced by the spacecraft environment.

c. Hardware Description. The basic experiment hardware consisted of three space-qualified immunodiffusion chambers patterned after commercial chambers and three syringes filled with serial dilutions of human antigens.

A passive cooler (modified thermos bottle) was developed to preserve the antigens and antibody-filled agar in the immune diffusion chambers at a temperature of $4^{o}C \pm 1^{o}C$ during the mission launch and activation phases. The complete hardware complement is illustrated in figure IV-2 and listed in tables VI-6 and VI-7.

2. Experiment Operation. The ED32 passive cooler and contents were transferred from the Command Module to the OWS food chiller on DOY 211. A total time of 51½ hours elapsed from prelaunch installation of the passive cooler in the CM until transfer to the OWS food chiller. This was the maximum permissible time (determined by test) to maintain the temperature limit required to preserve the biologicals.

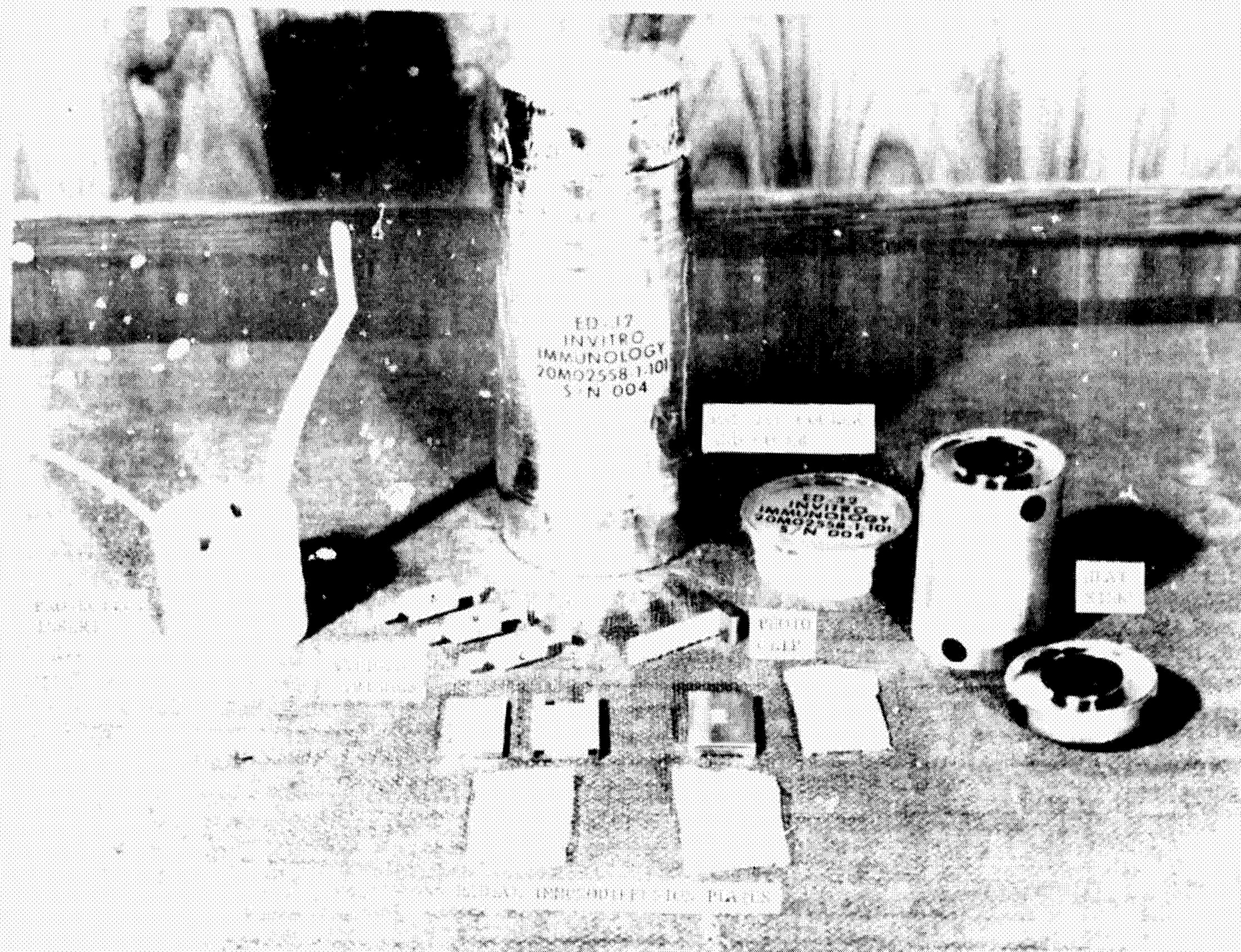


FIGURE VI-2. ED32 EXPERIMENT HARDWARE

TABLE VI-6 ED 32 EXPERIMENT HARDWARE

Experiment Equipment	Function
Immunodiffusion (I/D) chambers (3 ea) with cover slips and covers	To contain antibodies, agar medium and antigens and to serve as the vessel for development of the precipitin reaction
Pre-filled antigen syringes (3 ea) with caps	Three (3) serial dilutions of antigen test inoculum
Photographic clip	Hold I/D chambers for photography
Passive cooler and insert (Thermos bottle)	Preserve biologicals during launch and activation

TABLE VI-7 ED 32 EXPERIMENT SUPPORT HARDWARE

Experiment Equipment	Function
Nikon F 35 mm camera	To photograph immunodiffusion plates
55mm Lens for Nikon F (vis. f 4 1/125 secs)	Normal camera lens
Lens Adaptor (E-2 Nikon)	To permit close-up photography
35mm Film, Cassette type SO168	Photography
OWS Film Vault	Film Stowage
Transport Cooler	Temperature Control (prelaunch)
Experiment Log Book	Record Experiment Data
Scissors	Open plastic bags

The Science Pilot initiated the experiment on DOY 223 with no apparent problems. The voice transcripts indicate that the performances were normal and that the functional objective was met. Verification of these facts awaits detailed analysis of the returned films.

3. Experiment Constraints. The experiment constraints were successfully met during the mission.

4. Hardware Performance. The experiment hardware performance was nominal.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. The return data consisted of 36 frames of 35 mm photography together with a log of the times at which the photographs were taken.

7. Anomalies. There were no anomalies reported for this experiment.

C. Experiment ED41 - Motor Sensory Performance

The Student Investigator for Experiment ED41 was Miss Kathy Jackson, Clear Creek High School, Houston, Texas. She was assisted by a NASA Science Advisor. The hardware was designed and built by MSFC.

1. Experiment Description. Standardized eye-hand coordination tests have been widely used in the evaluation of industrial tasks and their resultant fatigue effects. Little or no comparable quantitative data has been acquired from manned space programs. Such data may be of significant value in the establishment of procedures, equipment and assigned crew tasks for future space missions.

a. Objective. The objective was to obtain motor sensory performance data including quantitative information from the performance of fine, manipulative tasks under prolonged weightless conditions. Comparison of inflight Skylab performance data with pre- and post-flight tests on the same subject and correlation with the copious industrial data will provide information on the space environment effects.

b. Concept. A standarized University of Michigan eye-hand coordination test was to be used to measure motor sensory performance. Existing data on numerous test subjects under varying test conditions provide a statistically meaningful measure of astronaut capability. The test was to be performed early, near the middle, and late in the mission to evaluate adaptation to, and degradation due to exposure to prolonged weightlessness.

c. Hardware Description. The hardware consisted of a space qualified version of a standard 119-hole-aiming-pattern maze and a pencil-like stylus. This maze consists of a set of 1/8 inch diameter holes arranged in a specific pattern. The stylus insertion in a hole resulted in an impact on a mechanically isolated back plate instrumented with an accelerometer. The accelerometer generated a signal pulse each time the stylus struck the back plate. This signal pulse was shaped and stretched to enable a single pulse detection with a sampling rate of 320 samples per second. The sampled signal pulses are recorded simultaneously with standard clock pulses to permit measurement of the time between pulses. These signals were recorded through the speaker-intercom assembly bio-medical channel for relay to the ground. Figures VI-3 and VI-4 illustrate the hardware and setup.

2. Experiment Operation. All three crewmen were to perform the experiment. Each performance consisted of three traverses through the maze.

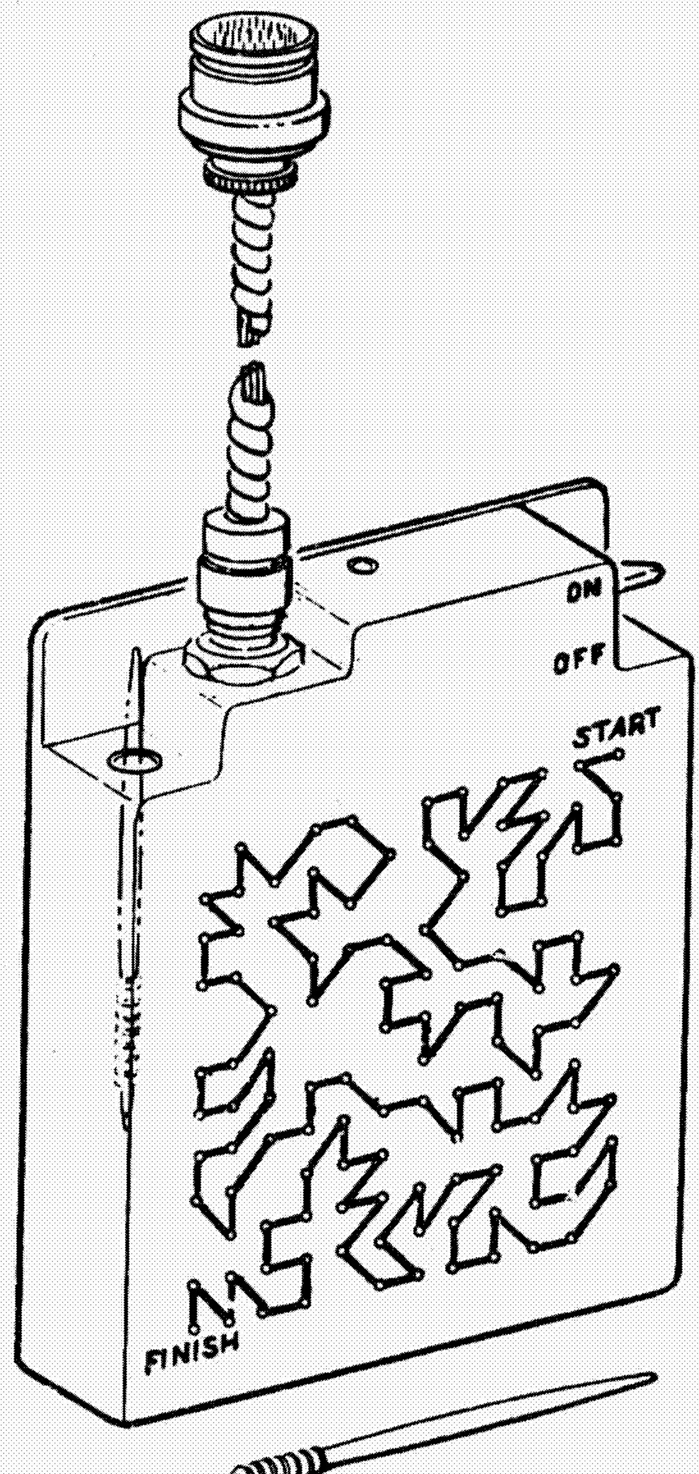
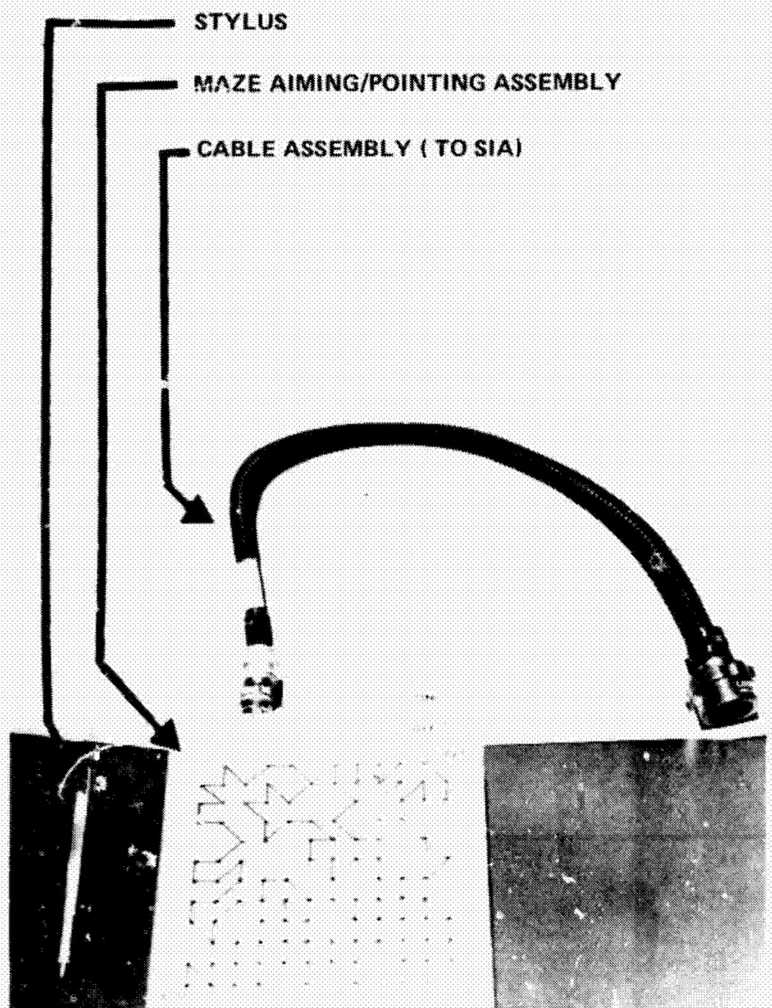
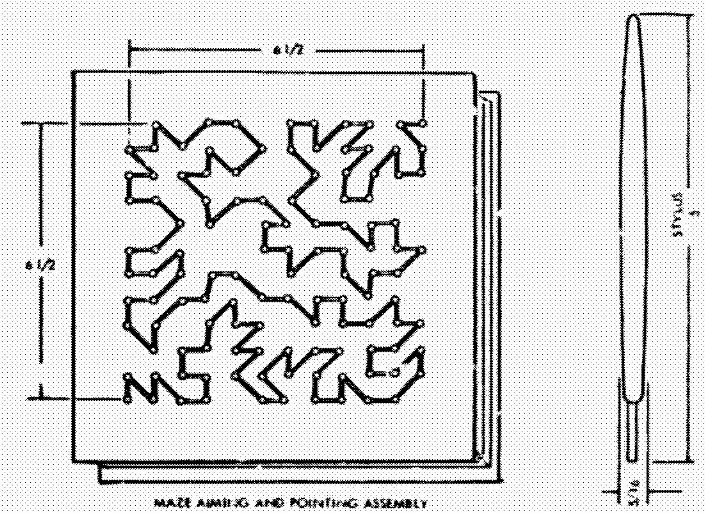


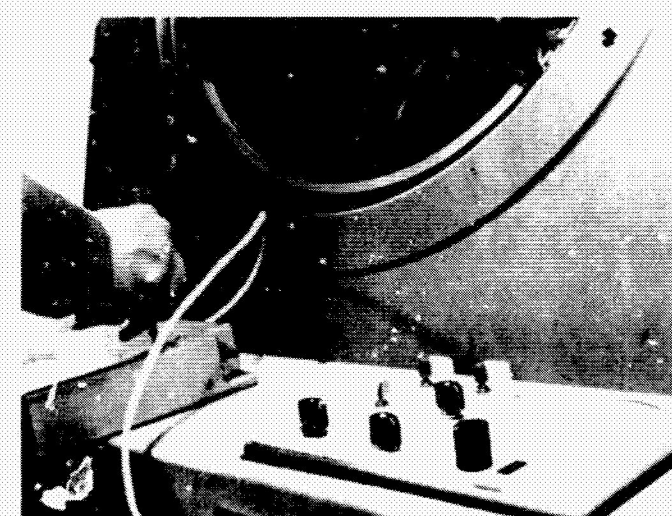
FIGURE VI-3. ED41 FLIGHT HARDWARE



ED 41 Motor Sensory Performance



Experiment System Details



Simulation Experiment Performance

FIGURE VI-4. ED41 SETUP

On DOY 329 all three crewmen performed the experiment satisfying the early mission requirement.

On DOY 357 the CDR and PLT successfully performed the experiment for some mid-mission performances.

On DOY 363 the SPT successfully performed the experiment completing the mid-mission performance.

On DOY 032 the final performance of ED41 was carried out by all three crewmen with a video tape record of the performance.

All performances were carried out with no significant problems.

3. Experiment Constraints. The experiment constraints were successfully met during the mission.

4. Hardware Performance. There were no apparent hardware anomalies other than a set up difficulty reported before the first performance. The crew commented during the debriefing that some gaps in the telemetry data might exist due to the lack of sensitivity in picking up the stylus insertion signal.

5. Experiment Interfaces. All experiment interfaces performed satisfactorily during the mission.

6. Return Data. All data was telemetered.

7. Anomalies. There were no anomalies reported.

C-4

D. Experiment ED52 - Web Formation

The Student Investigator for ED52 is Miss Judith Miles, Lexington High School, Lexington, Massachusetts. She received guidance and assistance from a NASA Science Advisor. The hardware was developed and fabricated by MSFC.

1. Experiment Description. The orb-weaving spider's web requires a complex sequence of actions by the spider in its construction. Changes in the web form are a function of the spider's particular physiological condition. Certain web pattern characteristics may be altered while others are not. The web is a useful record of the spider's functional motor sensory apparatus. This fact has proven useful in pharmacological investigations and it is hoped that they may be equally useful in the investigations of the internal Skylab environment effects.

a. Objective. The objective is the comparison of the geometry and structure of a common Cross Spider's (Araneus Diadematus) webs built under Skylab conditions and under normal conditions.

b. Concept. Two Cross spiders were to be launched in the CM and released individually in a small cage in the OWS. Automatic motion pictures of the web building process were to be taken. The completed webs were to be photographed. Comparison of at least three webs built in orbit with all the test spider's pre-flight webs were to be made on the basis of; difficulties encountered, construction time, web structure and web material.

c. Hardware Description. The hardware consisted of equipment designed to protect the spiders during launch and confine them during experiment performance without affecting their activity in orbit. Tables VI-8 and VI-9 list each item of experiment and support hardware and its function. Figures VI-5, 6, and 7 illustrate the hardware and its usage.

2. Experiment Operation. On DOY 206, three days before the SL-3 launch, two araneus diadematus spiders named Arabella and Anita were loaded into vials, placed in a carrying case, and stowed in the CM.

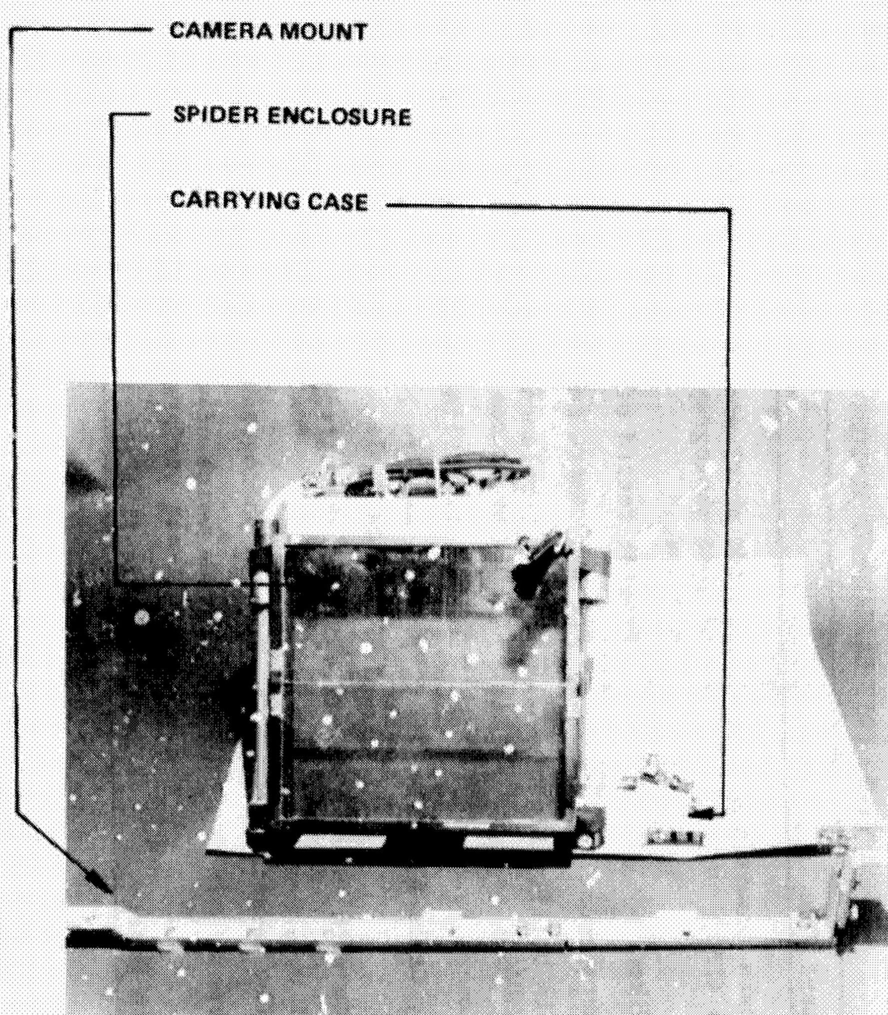
On DOY 212, four days after launch, the spider cage and automatic camera actuator were set up and tested. At this time, the automatic camera actuator failed to function according to design specifications. A malfunction procedure was developed for the crew's use (see paragraph 7). On DOY 217 the malfunction procedure was implemented, but to no avail. A manual mode for motion picture acquisition was instituted, and Arabella was released into the cage. She spent several hours in her vial and finally was forcibly shaken into the cage. She bounced back and forth within her cage several times before affixing herself to the screen covering.

TABLE VI-8 ED52 EXPERIMENT HARDWARE

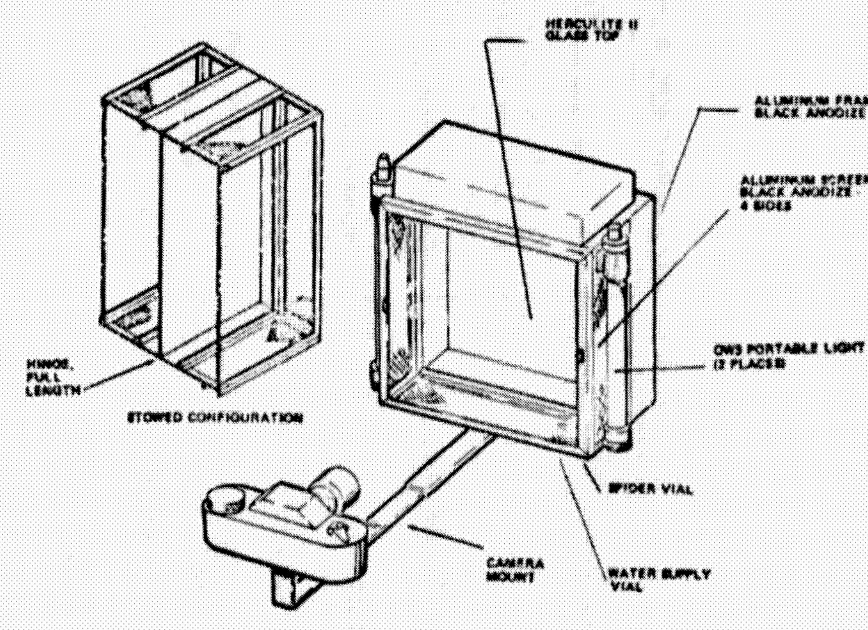
Experiment Equipment	Function
Enclosure	Provide housing for spider and water supply and permits observations of spider activities.
Araneus Diadematus Spider (two)	Test subject.
Food Supply (House Fly)	Provide an initial source of food for the spider.
Vials (two)	Provide means of transporting two spiders and two flies.
Water Supply Vial	Provide water during experiment.
Automatic Camera Actuator	Detect spider motion and start/stop motion picture camera.
Carrying Case	Hold two spider vials and one water supply vial for CM launch.

TABLE VI-9 ED52 EXPERIMENT SUPPORT HARDWARE

Equipment Item	Function
16mm Data Acquisition Camera (DAC)	Provide short sequences of motion picture photography of web building process.
35mm Nikon	Provide record of web.
ED Camera Mount	Provide camera support.
Portable Utility Light (two) MDAC	Provide supplemental lighting during filming sequences.
16mm Camera Power Cable	Conduct electrical power to 16mm camera.
Utility Cable Assembly (two)	Provide utility light to receptacle extension cable.
Cassette with film, 16mm 400 ft.	Provide photographic record.
35mm film cassette	Provide photographic record.
File Data	Provide voice or written record of experiment performance.
OWS Film Vault	Provide film storage.



View of Hardware



Hardware Details

FIGURE VI-5. ED52 WEB FORMATION HARDWARE

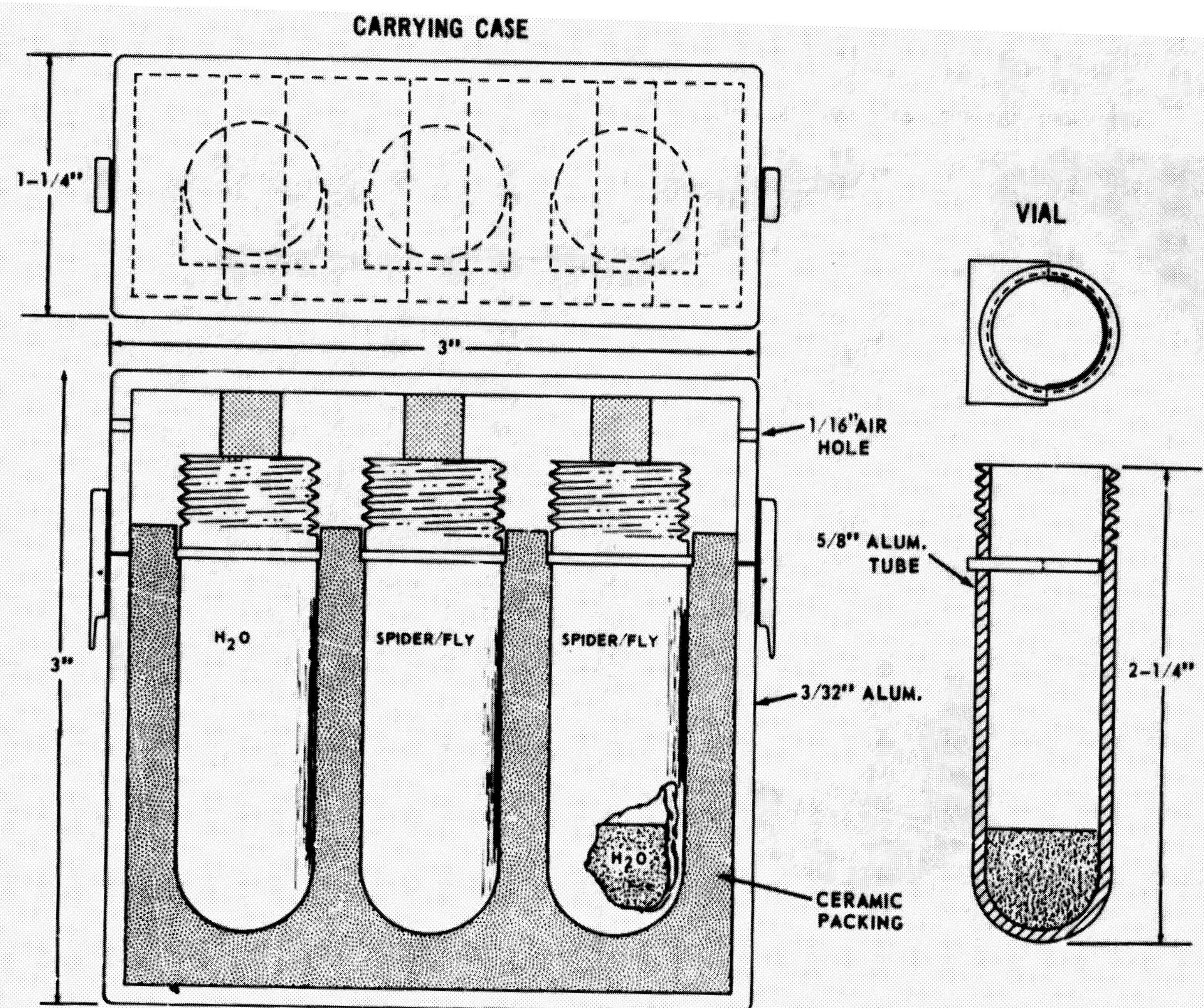


FIGURE VI-6. ED52 CARRYING CASE AND VIALS

FIGURE VI-7. FLIGHT-TYPE HARDWARE, TYPICAL ORBITAL OPERATION CONFIGURATION

The crew reported at 1408 GMT on DOY 218 that Arabella had constructed the initial framework for her first web. Photographs were made of the web which was completed the following day.

As a result of a voice transcript review, an entirely new experiment protocol included feeding the spiders rare filet mignon and providing them water on a periodic basis to keep them alive for return and complete laboratory analysis.

Both spiders were fed on DOY 222 and a video tape record of Arabella and her web was made the next day. On DOY 225, approximately half of Arabella's web was removed by the Crew. She then ingested the principal parts of the remainder and refused to rebuild the web. On DOY 226 the water supply was refurbished, and Arabella produced another web, completing it by the following day. The crew reported that Arabella had spun her best web to date.

On DOY 233, Arabella's web was completely removed and stored in the spider carrying case for return.

On DOY 238 Arabella was returned to her launch vial and all traces of her web removed from the cage. Anita was then transferred to the cage and a video tape record and 16mm movies were made of her initial reactions to freedom in a weightless environment. Her first night in the cage she spun only a rudimentary web in one corner, most likely the basic framework of a web. She also shared a small tab of prime rib with Dr. Garriott and seemed to have consumed at least part of it.

The SPT reported on DOY 241 that Anita had built a web covering about one third of the cage. A video tape record was made of this completed web. On DOY 243 a second video tape record of Anita and her web was made.

On DOY 259 the SPT reported finding Anita dead in her cage. Her body was transferred to her launch vial for return.

The revised protocol specified that Arabella, in her launch vial, should be fed rare filet mignon on DOY 261 and provided water on DOY 262. While no further voice transcripts were received concerning the spiders, the crew at debriefing implied that this was done. The launch vials and portions of each spiders' web were stowed in the spider carrying case, and subsequently transferred to the CM for return.

During the crew debriefing the Science Pilot commented that he felt the spiders took little or no cognizance of the water vial attached to the cage. This apparent omission on the part of the spiders to utilize the water contained therein cannot be construed

as a hardware or operational failure but rather an indication that some other means should be provided to water the spider in any future space experiments.

3. Experiment Constraints. The experiment constraints were successfully met during the mission with the exception of the first spider's late release (3 days).

4. Hardware Performance. The hardware performed as predicted with the exception of the automatic camera actuator malfunction (see paragraph 7).

5. Experiment Interfaces. All experiment interfaces performed satisfactorily. The spider cage was moved from its scheduled site to an alternate location when the decision was made to operate the experiment throughout the entire mission.

6. Return Data. TV and 16mm film records of Anita's deployment were returned. Both spiders and samples of their webs were returned. A total of 43 35mm frames of the various webs were returned.

7. Anomalies. On DOY 212 the SPT reported difficulty in operating the Automatic Camera Actuator. A lengthy voice transcript describing his difficulties and subsequent events revealed that the manual mode of the actuator was operable but the signal flow in the Automatic Mode failed to operate the camera.

Since no provisions were made for inflight maintenance and only minor adjustments were possible the malfunction procedure uplinked to the crew was tailored to verification of the adjustment procedures.

On DOY 217 these adjustment procedures were implemented by the SPT to no avail and the manual mode was instituted resulting in loss of capability to photograph the spiders while building a web.

The automatic camera actuator device (ACAD) operates on the same basic principle as an ultrasonic intrusion alarm system. An ultrasonic field pattern is set up in the spider cage by an ultrasonic transducer. The normal field pattern is sensed by means of a threshold detector, with input supplied by the ultrasonic receiver. Any disturbance resulting from either insertion of a foreign object or motion into the "static" sonic field results in a change in the signal level received by the ultrasonic receiver. This change in signal level is amplified and used to energize a detector relay, the contacts of which, when closed, permit power flow to the lights directly and to the camera remote control actuating system through a switching relay. Upon cessation of motion within the ultrasonic field pattern (spider cage) the second change in received signal level de-energizes the detector relay and delivers a transient signal to the switching

circuitry, activating the time delay system delaying the turn off of the camera by approximately 2 to 10 seconds, the lights remaining on.

In the manual mode the lights and camera are operated by manually operated switches.

The lack of a proper triggering signal in the automatic mode can be attributed to the failure of any one or more of several key components. Without return of the flight hardware for detailed analysis, isolation of the actual cause of the failure is impossible. It is presumed that the cause of the failure was a thermally induced problem resulting from the abnormally high temperatures experienced on SL-1.

E. Experiment ED61/62 - Plant Growth/Plant Phototropism

The Student Investigators for Experiment ED61/62 are Joel Wordekomper of Central Catholic High School, West Point, Nebraska and Donald Schlack, Downey High School, Downey, California. They were assisted by a NASA Science Advisor. The hardware was developed and fabricated by MSFC.

1. Experiment Description. Plants grown in an earth environment exhibit apparent involuntary movement of the roots and stems (tropism) under the influence of gravity (geotropism), water (hydrotropism), and light (phototropism). Investigations of these phenomena in space have been limited to the bio-satellite program with the longest duration flight being about 56 hours. The SL-4 56-day mission provided an ideal opportunity for such a study.

a. Objective. The first objective is to determine the difference in root and stem growth and orientation between rice plants germinated in zero-g and those germinated on earth under similar conditions. The second objective is to determine whether or not light can substitute for gravity (geotropism) in influencing plant growth in a particular direction in a weightless environment and, if so, to determine the minimum required light level. The ED61 experiment was represented by the first objective and ED62 encompassed both objectives.

b. Concept. Groups of three rice seeds each were to be implanted in a growth cell filled with nutrient agar and subjected to differing levels of ambient illumination. Periodic photography was to provide a record of the seed germination and development.

c. Hardware Description. The hardware required had sufficient commonality that one design served both experiments. Eight seed growth cells were provided in a package with two photographic windows provided in each cell. In the static growth mode, one window of each cell was closed and the other provided with an appropriate neutral density filter to allow illumination of the plants to vary from zero to near spacecraft ambient (see figure VI-8).

The seeds were implanted with an indexing seed planter which provided a launch and stowage container for the seeds before planting. Hollow seeding tubes were inserted into a set of three holes in each growth cell and penetrated the agar-filled cell to deposit three seeds near the center of the cell (see figure VI-9).

A camera bracket assembly was provided to assure uniform photographic parameters and to minimize crew effort (see figure VI-10). The support hardware is listed in table VI-10.

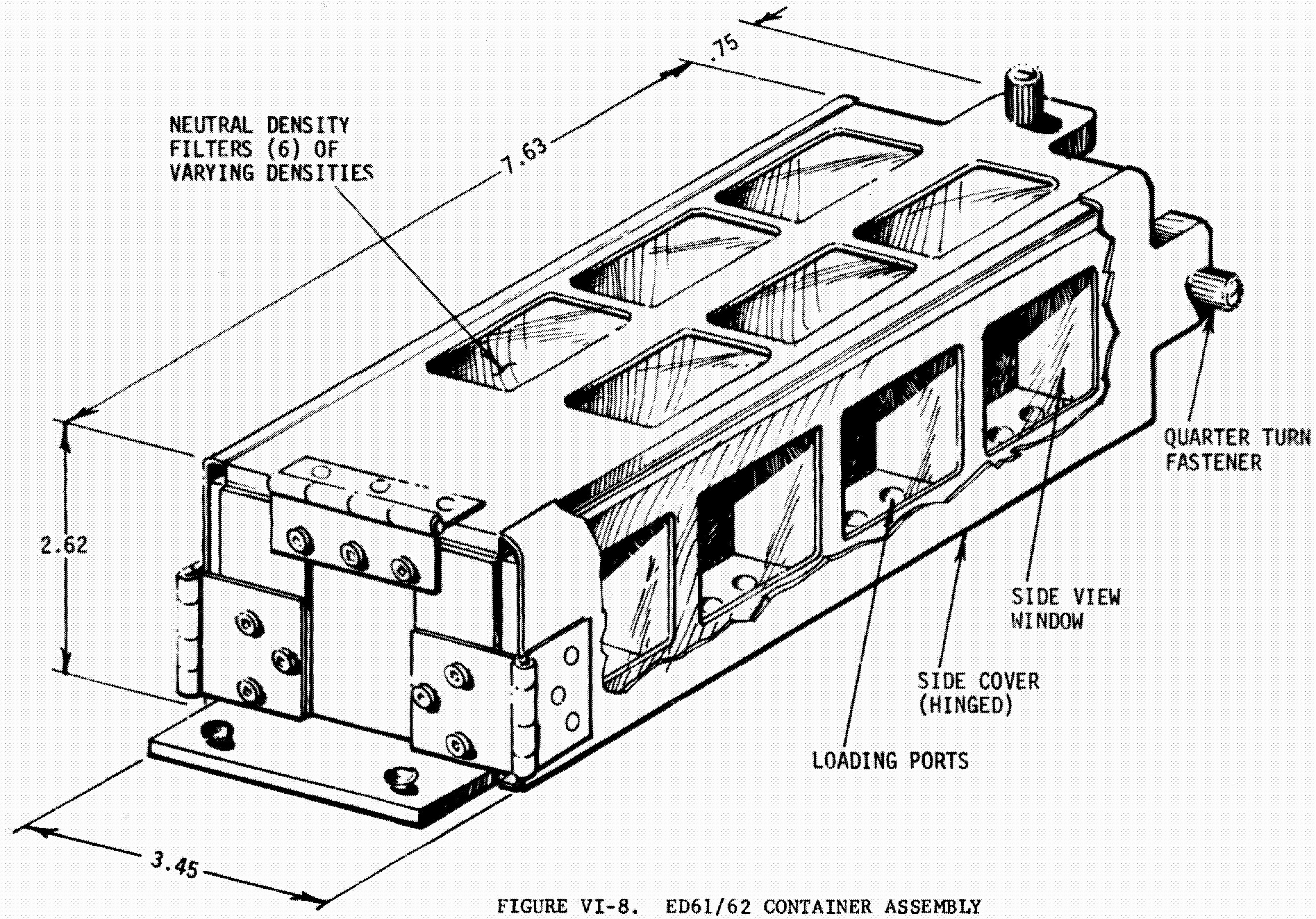


FIGURE VI-8. ED61/62 CONTAINER ASSEMBLY

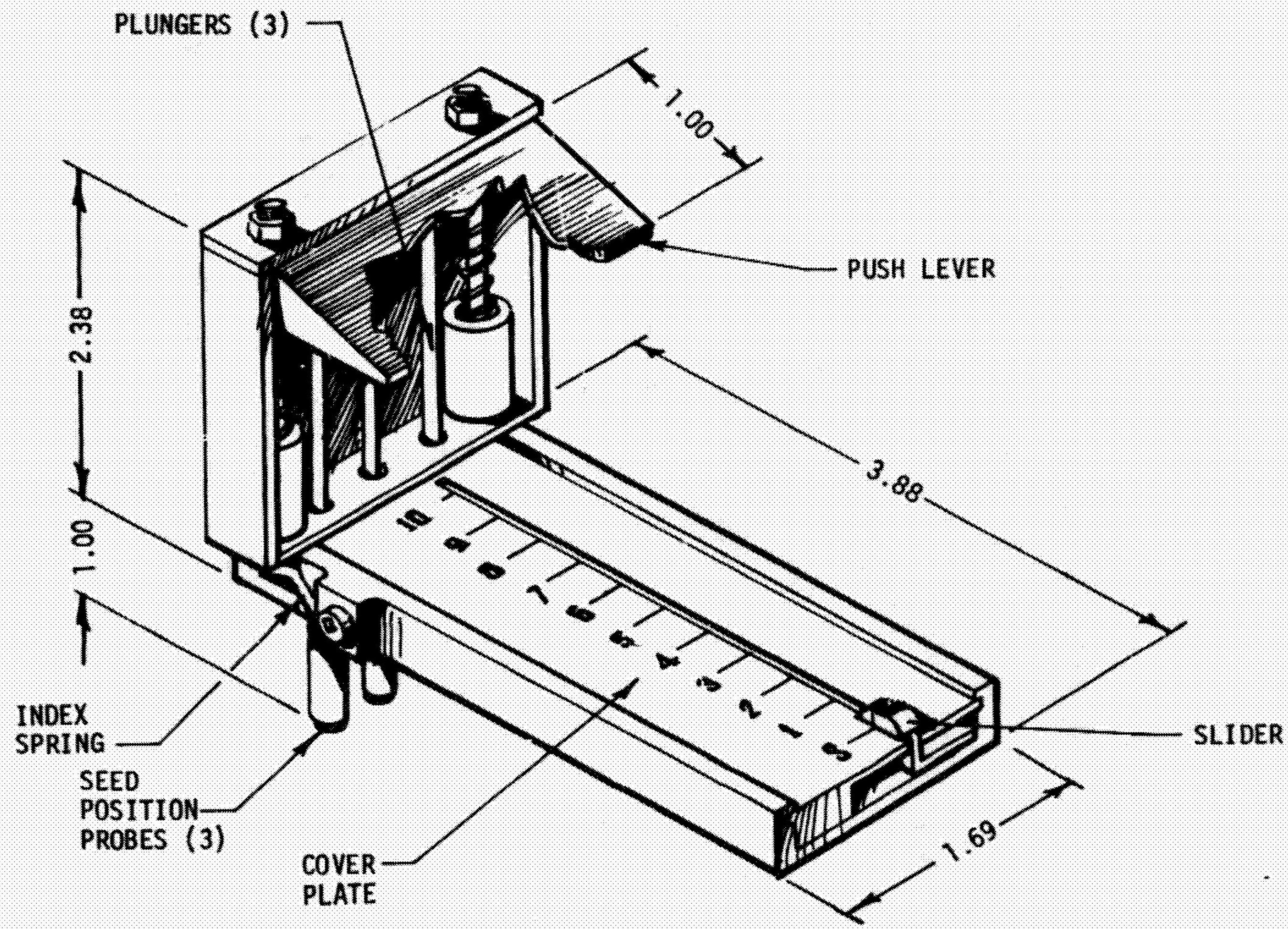


FIGURE VI-9. ED61/62 SEED PLANTER

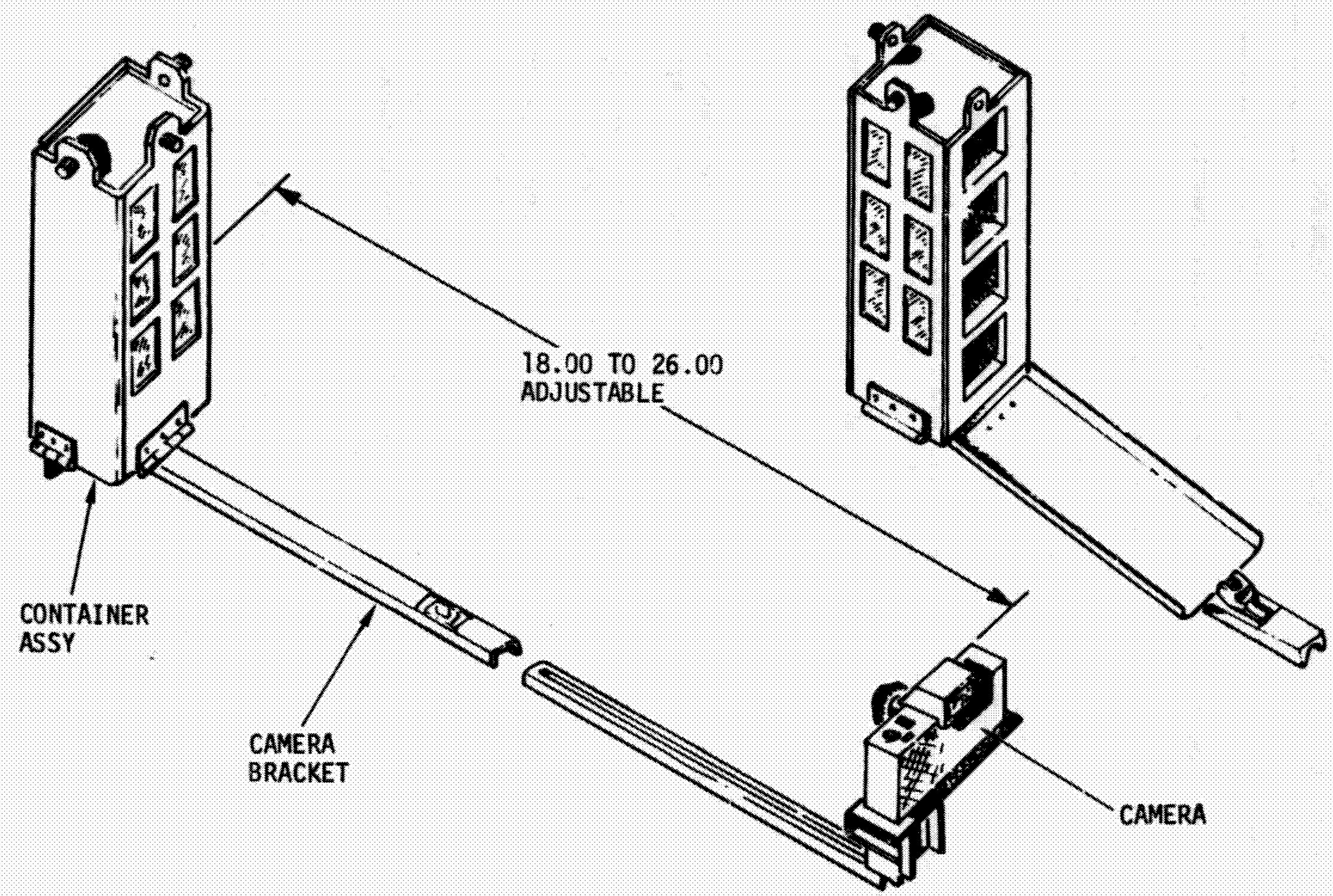


FIGURE VI-10. PHOTOGRAPHIC SETUP FOR ED61/62

TABLE VI-10 ED61/62 EXPERIMENT SUPPORT HARDWARE

Equipment Item	Function
Nikon F, 35mm camera	Photographed seed development.
55mm f1.2 lens	Normal camera lens.
Lens Adapter	Permit close up photography.
Portable high intensity photo lamp	Illuminated seeds for photography.
Cable assembly, utility high power (15 ft)	Provided power to portable high intensity photo lamp.
35mm film cassette Type S0168	Used for photography of seed embryos.
OWS Film Vault	Provided film storage.
ED camera mount beam	Assured proper camera exposure angle and focal distance during photography.
Camera end assy, ED camera mount	Provided interfaces between Nikon F camera and camera mount beam.
Bracket assy, ED61/62	Provided interfaces between compartmented container and camera mount beam.
Automatic spotmeter, 1 degree	Measured actual light level of the compartmented container operational location.
Cover, food table	Provided mounting location for ED camera mount to support experiment photography.

2. Experiment Operation. A mechanical seeder with rice seeds was launched on SL-1. Performance was scheduled over a 12-day period during the SL-4 mission. However, the high temperatures encountered during SL-1/2 resulted in supplying another mechanical seeder assembly and rice seeds on SL-3.

A different camera/lens adapter ring assembly was approved for launch and use on SL-4, because an SL-4 training session subsequent to SL-1 launch showed a significant photographic improvement.

On DOY 005 the Science Pilot planted the rice seeds. A minor anomaly associated with the use of the mechanical seeder resulted in no seeds planted in Compartment 2. There was some discussion at this time relative to the uniformity of incident illumination on the seed container. All seeds were exposed to less than desired illumination (see paragraph 7).

The photographic sessions proceeded per plan. An annotated event summary is given in table VI-11.

A procedure (removing the glass cover and filter plates from the container assembly) was added to permit plant exposure to the cabin atmosphere. The film remaining on DOY 017 could have been used to record this exposure. However, approval was delayed and when removal occurred on DOY 025, the remaining film had been routinely used. An additional film allocation was requested and approved, increasing the total numbers of frames above the planned level.

The requirement for an illumination level of at least 30 foot candles impinging on the cell windows was not met. Illumination was reduced from 5 to 20 foot candles due to incorrect growth container location as shown in figure VI-11.

The photographic performance requirements schedule was changed to match the plant growth rate and to conserve film for recording plant growth in cabin atmosphere.

4. Hardware Performance. All hardware performed as expected except the unexplained failure to implant seeds in Compartment 2. This apparent failure is probably due to a misinterpretation of the checklist (paragraph 7).

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

TABLE VI-11 SUMMARY OF EVENTS

GMT	Experiment Day	Event	Notes
2157-2230	00	SPT planted seeds	Labeling explained, compartment 2 has no seeds
0124	01	TV 68	VTR of expt performance
1848	01	Discussion of light levels	
1911	02	First photo session	Agar showed cracks, no observable seed development
1254	03	Second photo session	No observable growth
1248	04	Third photo session	Growth reported
2348 0100	04/05	SPT requested method of differentiation between stem and root	Support team reported root appears first. Stem emerges as end rolled leaf in thin membranes and should turn green a few hours after subjected to light
1713	05	Fourth photo session	SPT reported on growth of each seed
1701	06	Fifth photo session	SPT reported on growth patterns
0235	08	Sixth photo session with TV 69	SPT reported on growth patterns
1221	12	Seventh photo session	Green development reported
1742	16	Eighth photo session	
1754	22	Ninth photo session	
2252	25	Glass cover plate and filters removed from growth container	

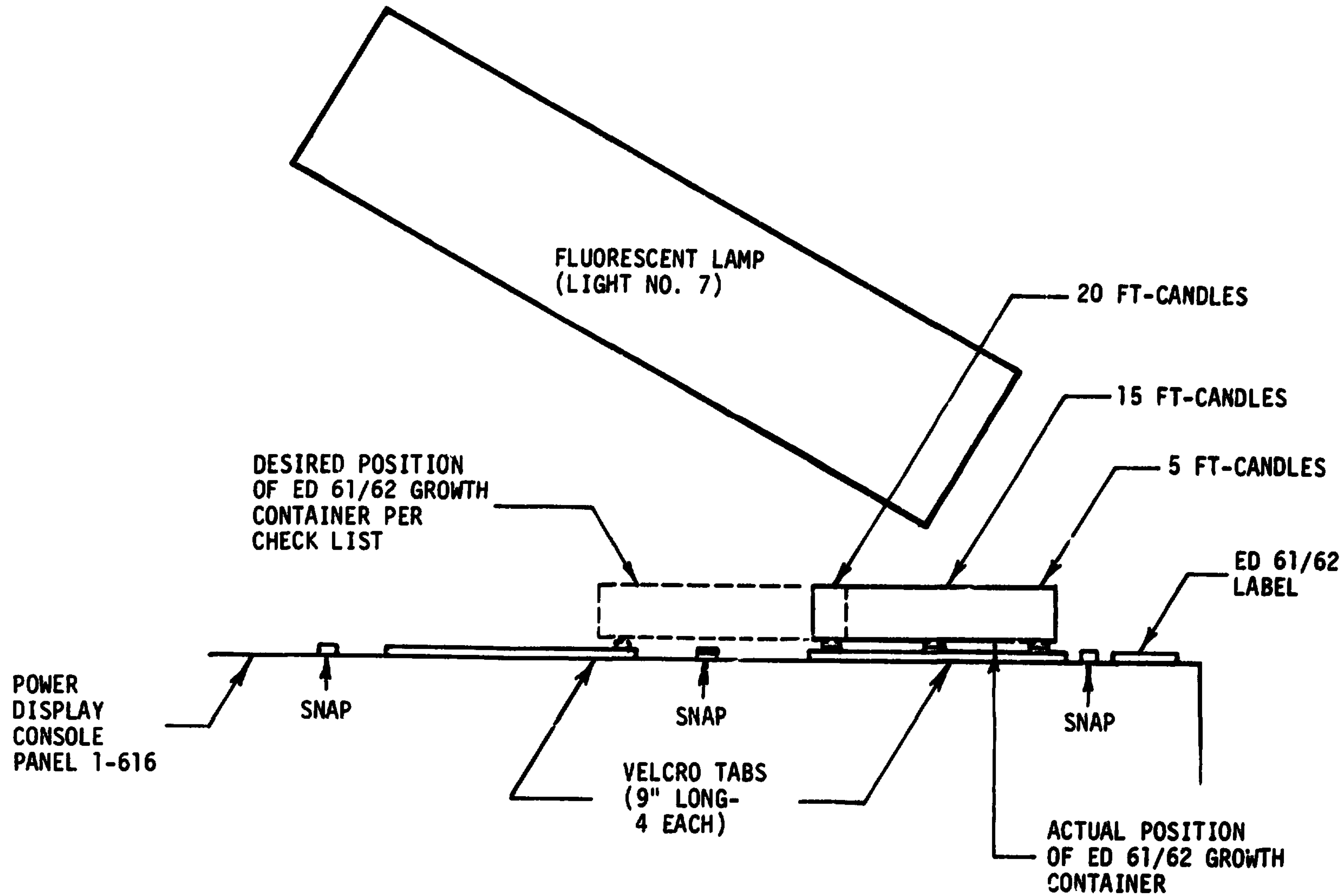


FIGURE VI-11. MOUNTING POSITION OF GROWTH CONTAINER RELATIVE TO ADJACENT LIGHT NO. 7, AS VIEWED FROM BELOW

6. Return Data. The data returned consisted of 59 frames of 35mm film. The 59 frames of 35mm film returned include two frames exposed following the removal of the glass covers and filter plates. The remaining seven to fifteen frames of film that appear to have been exposed based on the voice transcript have not yet been located. Supplementary data recorded on 16mm film from TV coverage of experiment preparation and operation on TV68 on DOY 005 and TV69 on DOY 013 is available.

7. Anomalies. There were four anomalies associated with this experiment. The first was the abnormally high temperatures encountered on SL-1. This caused concern for the rice seed viability. Ground tests were performed to assess the high temperature effects. It was determined that the germination probability was reduced from 0.8? to less than 0.50. A request was implemented to supply another mechanical seeder assembly containing rice seeds on SL-3.

The second anomaly concerned the light levels at the container assembly. During planting of the rice seeds, the Science Pilot reported non-uniform illumination of the seed container. He suggested moving the seed growth container to a position of more uniform lighting. It was not clear that the actual location of the container was not as specified in the checklist. It was recommended that the container be left where it was. (See figure VI-11). This condition was discussed at the crew debriefing and resolved that the container was improperly located on the velcro tabs that were mounted adjacent to the OWS light. This procedural error apparently resulted from an effort to minimize checklist verbage and crew training time, and an inappropriate experiment label locatior in the OWS.

The third anomaly was associated with the failure to implant seeds in compartment 2. This was probably a checklist misinterpretation. The ZERO slider position was intentionally left empty to obviate seed loss by inadvertent plunger operation. Voice transcripts suggest that compartment 2 was filled with the slider in the ZERO position.

The fourth anomaly, as yet unresolved, is the failure to return 64 frames of 35mm film per the basic protocol plus those additional frames resulting from the request of removing the cover plate and filters from the seed container. A voice transcript review indicates that there were between seven and fifteen frames of film exposed in addition to the 59 frames received.

F. Experiment ED63 - Cytoplasmic Streaming

The Student Investigator for ED63 is Cheryl Peltz, Arapahoe High School, Littleton, Colorado. She was assisted by a NASA Science Advisor. The hardware was designed and built by MSFC.

1. Experiment Description. Cytoplasmic streaming (cyclosis) is the movement of cytoplasm throughout a plant. The cytoplasm is a heterogeneous viscous material holding choroplasts (which provide plant nutrition) in suspension. The choroplast motion is the phenomena of interest and the small bodies about 10 microns in size are visible with the aid of a microscope.

a. Objective. The objective was to perform microscopic observations of wet slides prepared from the elodea plant leaf to determine the difference, if any, in the intracellular cytoplasmic motion between plants in a weightless environment and on the ground.

b. Concept. Three vials containing sprigs of elodea suspended in a nutrient agar solution were to be placed in the OWS under strong ambient illumination for a period of up to three weeks. As early as possible within the mission, a wet slide was to be prepared, with microscopic observations and photomicrographs made of the cytoplasmic streaming in a single elodea leaf using 400 power magnification. This observation/recording was to be repeated twice at approximately one-week intervals.

c. Hardware Description. The basic experiment hardware included commercial equipment. The specifically developed hardware elements included an experiment container providing a 5 psi environment, elodea vials, tweezers, microscope slides and slip covers. Tables VI-12 and 13 list the experiment dual support hardware and their functions. Figures VI-12 and 13 illustrate the hardware.

2. Experiment Operation

a. SL-3. The vials containing elodea sprigs were scheduled for deployment in the OWS within three days after the SL-3 launch. The cytoplasmic streaming observations were to be made at seven to ten days, 15 to 18 days, and 23 to 30 days after the SL-3 launch.

Four days prior to launch six elodea vials were prepared at MSFC. Three of these vials were placed in the experiment container in total darkness, and the container was sealed at 5 psia for flight. The other three vials were placed in total darkness in a normal earth environment to be used as ground control units.

TABLE VI-12 ED63 HARDWARE

Experiment Equipment	Function
Microscope slides (3)	Wet slide preparation
Slip covers (3)	With microscope slide
Tweezers	Removal of leaf from vial
Elodea vials (3)	Contained a sprig of elodea within a nutrient enriched agar medium.
Experiment container	Contained all experiment equipment.

TABLE VI-13 ED63 SUPPORT HARDWARE

Item	Function
IMSS microscope	Observe details of elodea cells
IMSS microscope mod kit (2 penlight batteries, 1 mirror assy, 1 GE #243 lamp)	Modify IMSS microscope to allow photo-micrography
Microscope Adapter	Enable photography of cytoplasmic streaming
Data Acquisition Camera	Photograph cytoplasmic streaming
Remote control system assy., 16mm DAC	Controls frame rate and power application for DAC
Cable power, 16mm Camera OWS/MDA	Provide power to DAC
16mm film cassette, 400 ft., Type S0168	Photograph cytoplasmic streaming
OWS Film Vault	Film storage
IMSS incubator/work station	To support photomicrography
Automatic spotmeter, 1 Degree	To measure actual light level of the elodea vial operational location

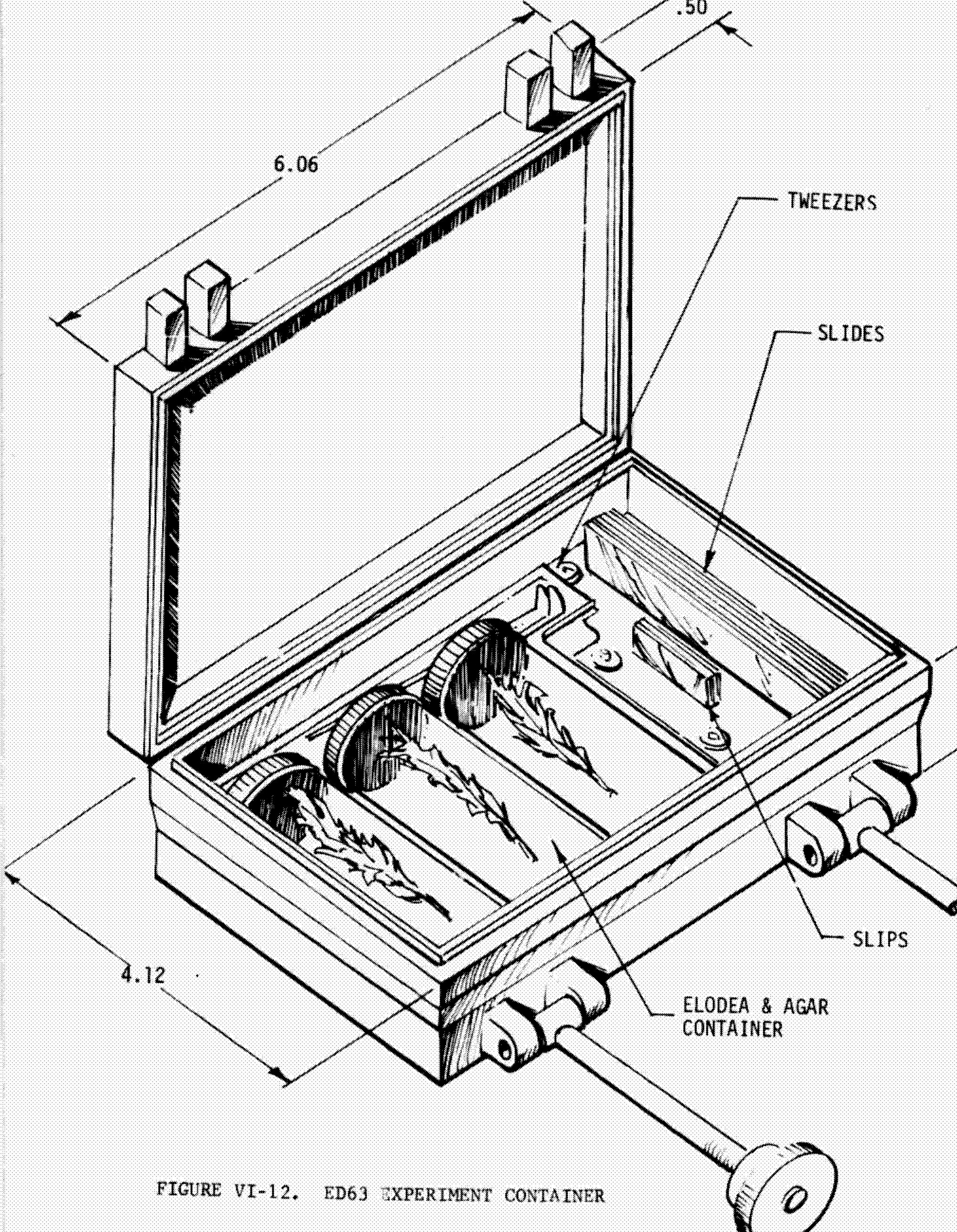
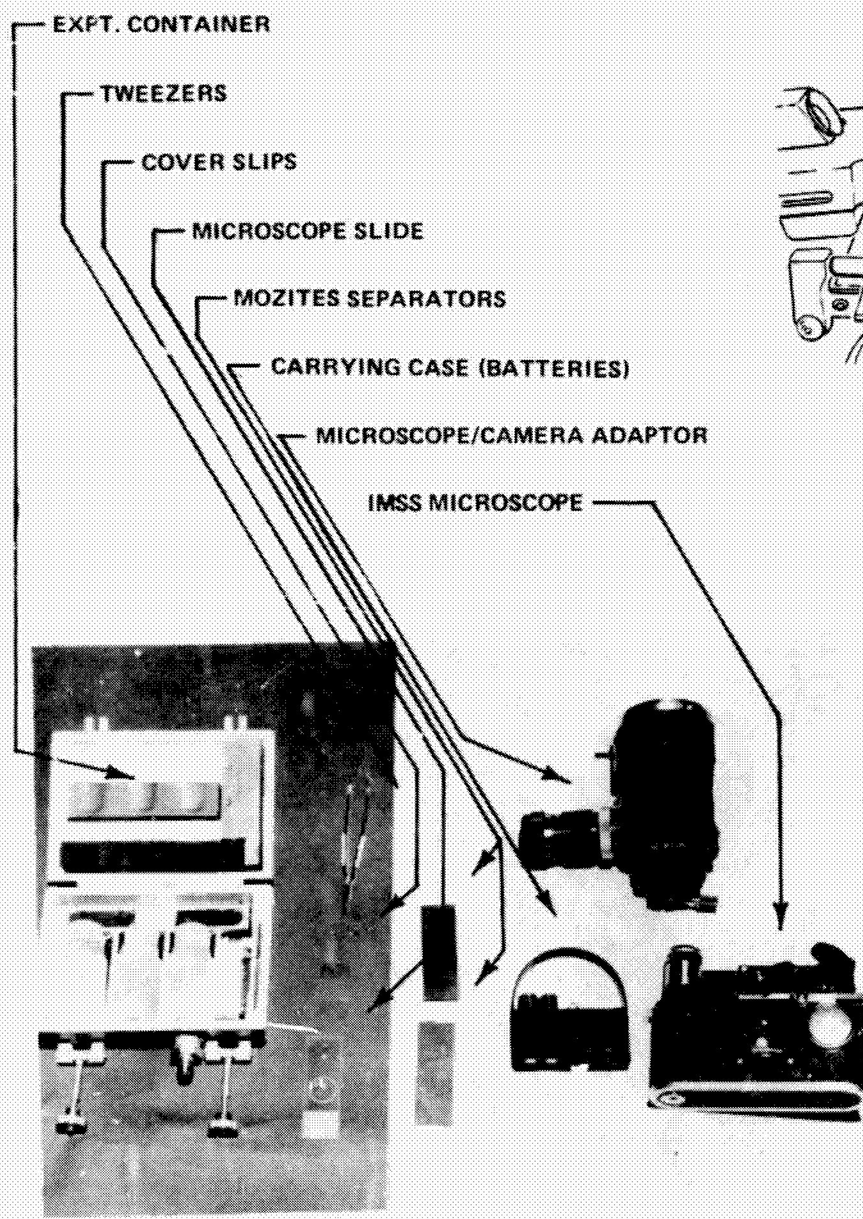
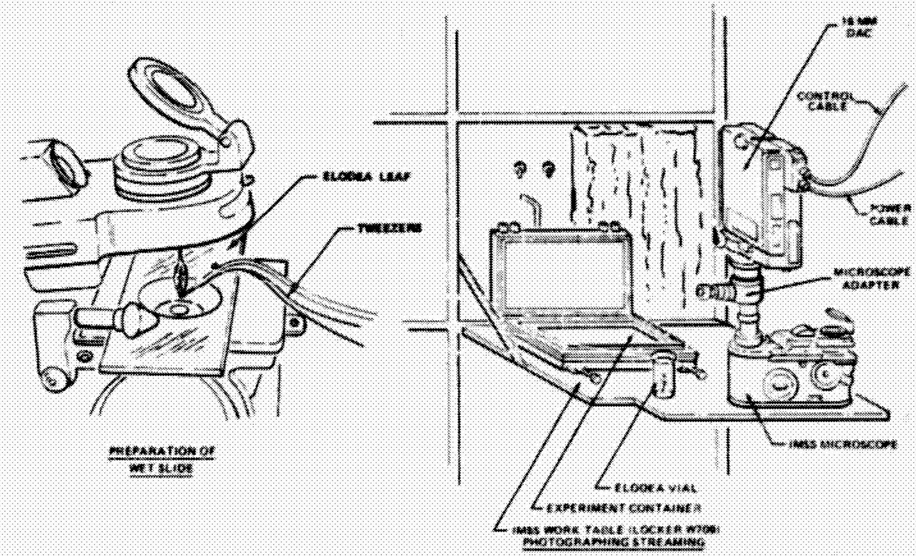


FIGURE VI-12. ED63 EXPERIMENT CONTAINER



View of Hardware



Hardware Description

Simulating Wet Slide Preparation

FIGURE VI-13. ED63 EXPERIMENT HARDWARE

On DOY 212, after eight days in total darkness, the three flight vials were removed from the experiment container and placed in the specified growth location on the cable tray near wardroom light No. 1. At the same time the ground test unit was opened and examined. Two of the three ground control plants appeared dead and exhibited no streaming; the third plant appeared healthy and did show cytoplasmic streaming.

As the flight plants might be in a similar condition the following ED63 checklist change was provided for the crew:

> At first observation examine all three elodea plants in sequence until a viable plant is found or all plants are verified to be dead.
>
> Criteria for judging health of plants:
>
> > Detection of hydrogen sulphide odor from plant.
> >
> > Degree of resistance to removal of leaf from stem.
> >
> > Observation of cytoplasmic streaming.
>
> Only those vials containing dead plants will be discarded.
>
> Vials containing healthy plants will be retained for succeeding observations.

On DOY 223, the SPT reported performing the first ED63 observation as illustrated in figure VI-14. He prepared two slides from the plant that exhibited the greatest potential for viability but observed no streaming. The 16mm motion picture film was exposed in the hope that the film might reveal streaming even though it was not visually observable. Each elodea vial exhibited a rotten egg odor and the leaves from each plant exhibited little resistance to removal from the parent stems. Based on the observation of streaming from the marginal ground control plants, a request was made of the SPT to examine leaves from the remaining two vials under the microscope. On DOY 226, the SPT performed this examination and did not observe any streaming. It was assumed the plants had died.

The returned film failed to show any images (see paragraph 7).

As a result, a new launch packaging method and revised procedures were prepared for launch and performance on SL-4.

b. SL-4. To increase the potential for plant survival, the SL-4 launch configuration was revised to enable the plants to receive available light at all times except during the actual launch

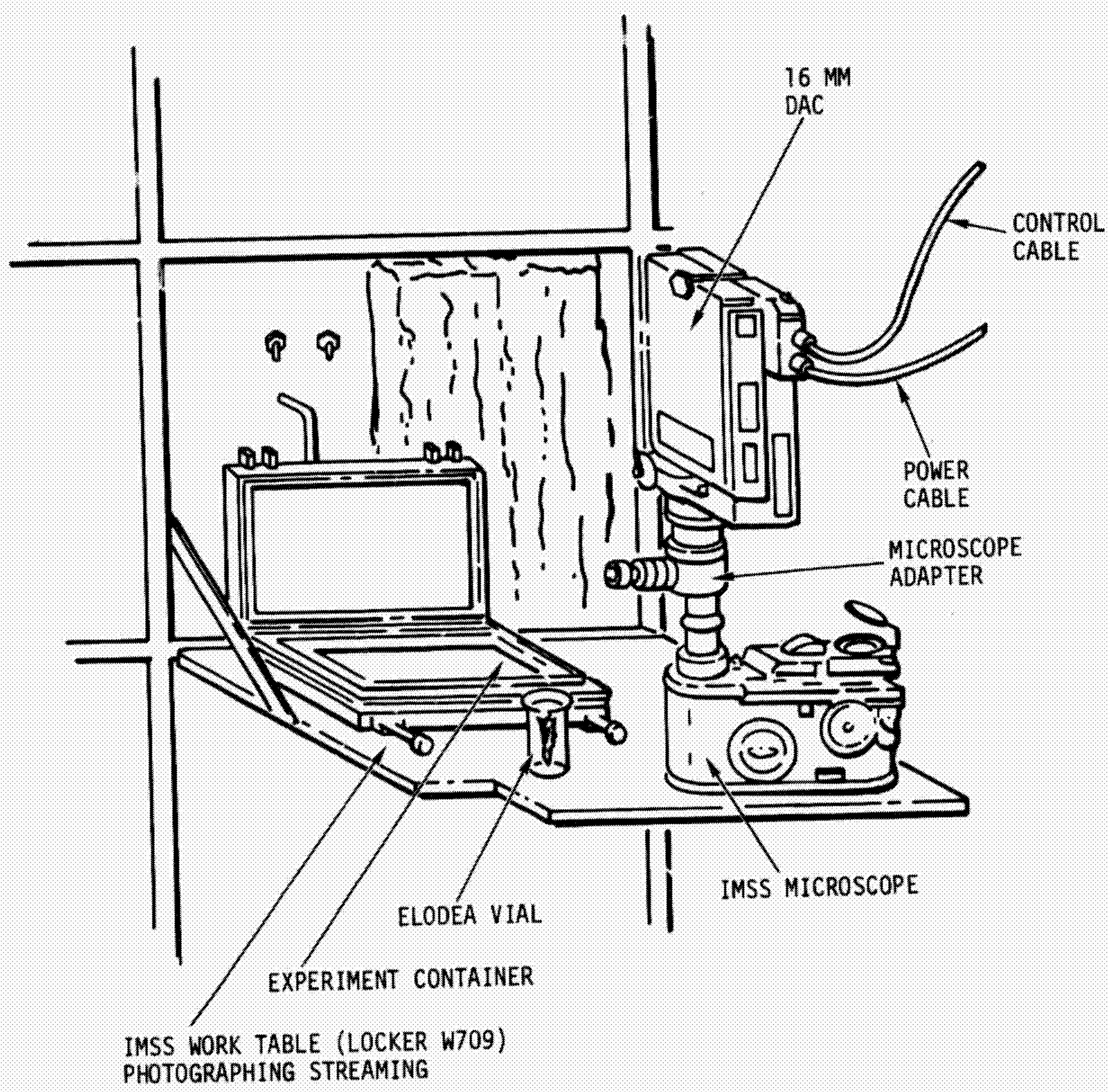


FIGURE VI-14. ED63 DATA ACQUISITION PHASE

period as shown in figure VI-15. The elodea vials were prepared four days prior to launch, and hand carried to KSC two days prior to launch with ambient light impinging on them. The launch package was stowed in CM locker U-F and was deployed at the CM window on DOY 321 at approximately 0305 GMT. Corrective action was requested of the crew for the plants to be removed from the window to avoid over-stimulation of the plant's metabolism and over-heating of the agar/plant combination due to exposure to direct sunlight.

On DOY 329, the 15th day following vial preparation and four to six days beyond the specified time, the SPT reported the first elodea leaf microscopic examination. He reported that one vial, heavily filled with elodea plant, exhibited a definite hydrogen sulfide odor and appeared dark green in color. A second vial, less heavily filled with elodea, had a slight odor, and the third vial, the one with the least amount of plant in it, gave off no odor and appeared the healthiest of the three samples. It was apparently this third plant that the SPT observed under the microscope. At the debriefing, he reported that streaming did appear in the leaf he examined. It appeared approximately normal in the leaf stalk area. When he attempted to take photographs through the microscope, he reported some difficulty. There was an apprent procedural error in removing the microscope eye piece before installation of the camera/microscope adapter. As a result the films returned were not usable.

Following confirmation that ED63 had been attempted, an observation was made of the ground control units. All three control plants appeared healthy and exhibited streaming. There was no reason to believe that the flight plants were not also healthy. The reported hydrogen sulfide odor present in flight was most likely due to the additional waste products developed from the algae (dark green) vial.

The condition described in the voice transcript (message 330 16 36 23 on Tag Tape 330-07/T121) relating to a limited field of view, was simulated on the ground by removing the 10 power eyepiece (see figure VI-16) from the microscope prior to installation of the camera adapter. A comparison of the normal "bright" field observed through the camera adapter eyepiece with the microscope eyepiece in place and removed (see figure VI-17) substantiated the removal of the microscope eyepiece.

On DOY 339 a second microscopic observation of the plants was made. The microscope/camera difficulty was corrected but all three plants were apparently dead. All three plants showed little resistance to leaf removal.

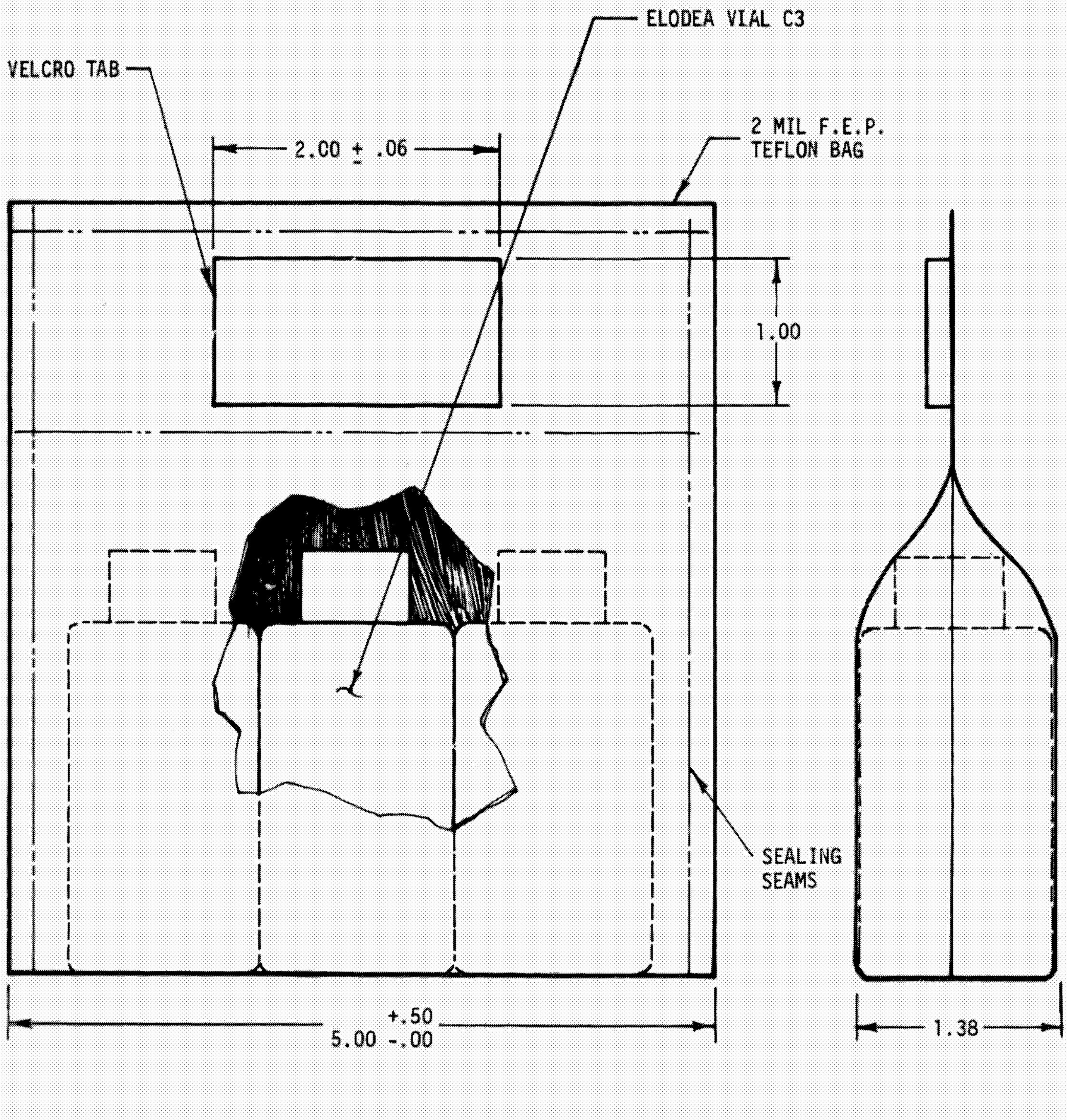


FIGURE VI-15. ED63 LAUNCH CONFIGURATION (SL-4)

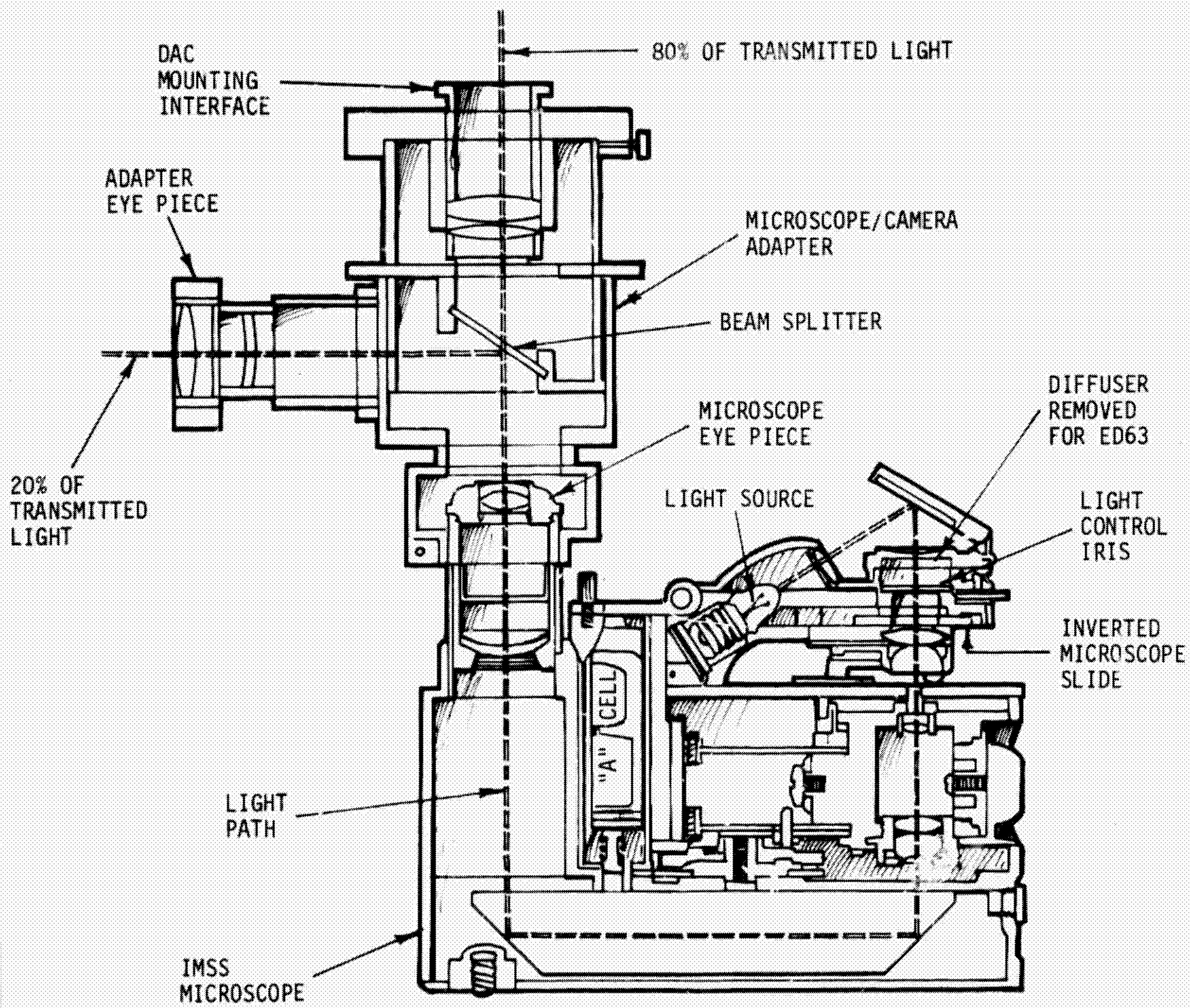
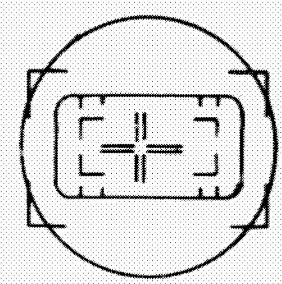
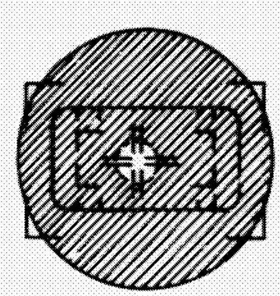


FIGURE VI-16. ED63 MICROSCOPE/ADAPTER/CAMERA SYSTEM



NORMAL APPEARANCE OF FIELD-OF-VIEW
THROUGH MICROSCOPE ADAPTER EYEPIECE
WITH 10X MICROSCOPE EYEPIECE IN PLACE -
400 MAGNIFICATION



APPEARANCE OF MICROSCOPE FIELD
THROUGH MICROSCOPE ADAPTER
EYEPIECE WITH 10X MICROSCOPE
EYEPIECE REMOVED - 40 MAGNIFICATION

FIGURE VI-17. COMPARISON OF MICROSCOPE IMAGES
(10X EYEPIECE "IN" - "OUT")

The SPT reported that the light appeared inadequate for good photography even with the microscope iris wide open, and the installation of fresh batteries and the microscope mirror assembly. This fact was verified by the somewhat under-exposed but usable film. The SPT also experienced some difficulty in getting proper focus.

Following the demise of the elodea plants, an effort was initiated to establish the feasibility of observing cytoplasmic streaming in the rice plants of ED61/62. On or about DOY 014, an Action Request was submitted to remove the glass cover plate and neutral density filters from the ED61/62 rice plant growth container to enable access to various portions of the plant. Instructions were supplied for preparation of wet slides from the rice plant emerging-leaf structure (coleoptile), root hairs, and stem/leaf structure near the root head. On DOY 028, the request intent was approved and a general message instructing the crew to perform the ED61/62 modifications was transmitted. On DOY 030, the procedure for observation of cytoplasmic streaming in the rice plants was provided for the crew's use. Other higher-priority activities precluded the implementation of this procedure and no meaningful data was obtained.

3. <u>Constraints</u>. The experiment constraints were satisfactorily met during the mission except for the following:

a. SL-3. A deployment constraint that the elodea vials be placed in an area providing at least 20 foot-candles of illumination on the vials within three days after launch was exceeded by one day.

The operational schedule constraint that the examinations and film recordings be made 7 to 10 days, 15 to 18 days and 23 to 30 days after launch were actually performed at 8 days after launch and the balance terminated as the plants were no longer alive.

b. SL-4. The location constraint that the experiment package be deployed within 24 hours in a convenient CM location but not in direct sunlight was violated when the package was placed in a sunlit CM window for several hours.

The operational schedule constraint that the examinations and film recordings be made 5 to 7 days, 12 to 15 days and 21 to 25 days after launch were actually exceeded by 4 and 4 days, and the third performance terminated as the plants were no longer alive.

A hardware configuration constraint that examination and film recording utilize a 400 power microscope magnification was negated by inadvertent microscope eyepiece removal during microscope/camera adapter installation. This resulted in the photograph magnification being reduced from 400 to 40 power.

4. Hardware Performance. The hardware performed as expected. The failures on SL-3, the demise of the plants and the incorrect exposure of film, were not ascribed to hardware performance nor was the demise of the plants and the inability to obtain good photography on SL-4. (See paragraph 7).

5. Experiment Interfaces. All experiment interfaces performed satisfactorily during the mission.

6. Return Data. The return data for ED63 was to consist of approximately 50 feet of 16mm SO168 film for each of the three scheduled observations, and the voice records of the conditions observed.

The SL-3 return data included 50 feet of blank film taken of the initial observation and a TV downlink (no scientific data) showing ED63 operations on DOY 226.

The SL-4 return data included: 90 feet of film taken of the first observations and 30 feet of film taken of the second observation. The first observations film was of no value due to the procedural error while the other was acceptable though slightly out-of-focus.

7. Anomalies. SL-3. The first anomaly was the death of the elodea plants in all three vials before streaming observations could be made, 19 days after preparation of the plants, and 8 days in darkness. The apparent cause was an excessively long exposure to total darkness. Pre-flight tests established optimum agar media, optimum nutrient constituents, effects of five psia oxygen rich environment and vibration, suitable launch configuration, and allowable exposure duration to total darkness. During the mission, three ground control plants were exposed to total darkness at room temperatures with daily examination. One plant died per day on the eighth, ninth and tenth day. Three other plants were tested for 28 days in 30-35 foot-candles of incident light and 20°C to 23°C temperature. All plants appeared healthy and exhibited streaming. An eight-day exposure resulted from a 1-day early preparation of the plants and a 1-day delay in deploying the plants.

The second anomaly was the failure of the exposed film to exhibit an image. This anomaly has not yet been resolved. The general checklist procedure required that the IMSS microscope mirror assembly including a diffuser be replaced by the ED63 microscope mirror assembly which does not have a diffuser and that fresh batteries be installed. When observation of a slide was made, the mirror assembly iris controlling the amount of light incident on the slide required an adjustment based on a subjective evaluation of the illumination level. Since the Skylab ambient light levels are significantly lower than normal ground lighting, the astronaut's visual adaptation to this lower illumination level may have resulted in t[illegible]

inadvertent selection of lower-than-desired brightness of the microscope field. This lower field brightness could also have been du to a slight misalignment of the microscope mirror assembly (figure VI-18). There was no other apparent cause for the lack of image on the film.

These anomalies influenced the request for and approval of performance on SL-4.

SL-4. Photography from the first observation was unusable because of the inadvertent removal of the microscope eyepiece during microscope adapter installation.

All plants were reported dead on DOY 337 during the second observation. The early death can possibly be attributed to the following causes:

Over stimulation caused by several hours of exposure to direct sunlight from the CM window. A sustained temperature in excess of 10.°F will kill elodea. Bright light stimulation of the plant and algae speeds up metabolic processes. This results in rapid consumption of nutrients adjacent to the plant leaves, and rapid contamination of the surrounding agar with plant waste products.

The plants gas products generated during normal metabolic processes percolate through the agar as a result of buoyancy effects in earth's gravity. These gases may remain near the plants surfaces when in orbit.

The unknown effects of a zero-g environment on the plant.

The problem encountered during the second observation with regard to microscope focus resulted in a usable but less-than-sharply-defined image. This de-focusing could have been the result of an excess amount of agar adhering to the elodea leaf raising the slide cover plate and yielding an overly thick slide. The depth of field of the microscope at 400 power is very small and any deviation from flatness of the slide or an excess in slide thickness could result in interference between the microscope lens and the slide coverslip either of which could have produced the observed soft-focus. (See figure VI-16).

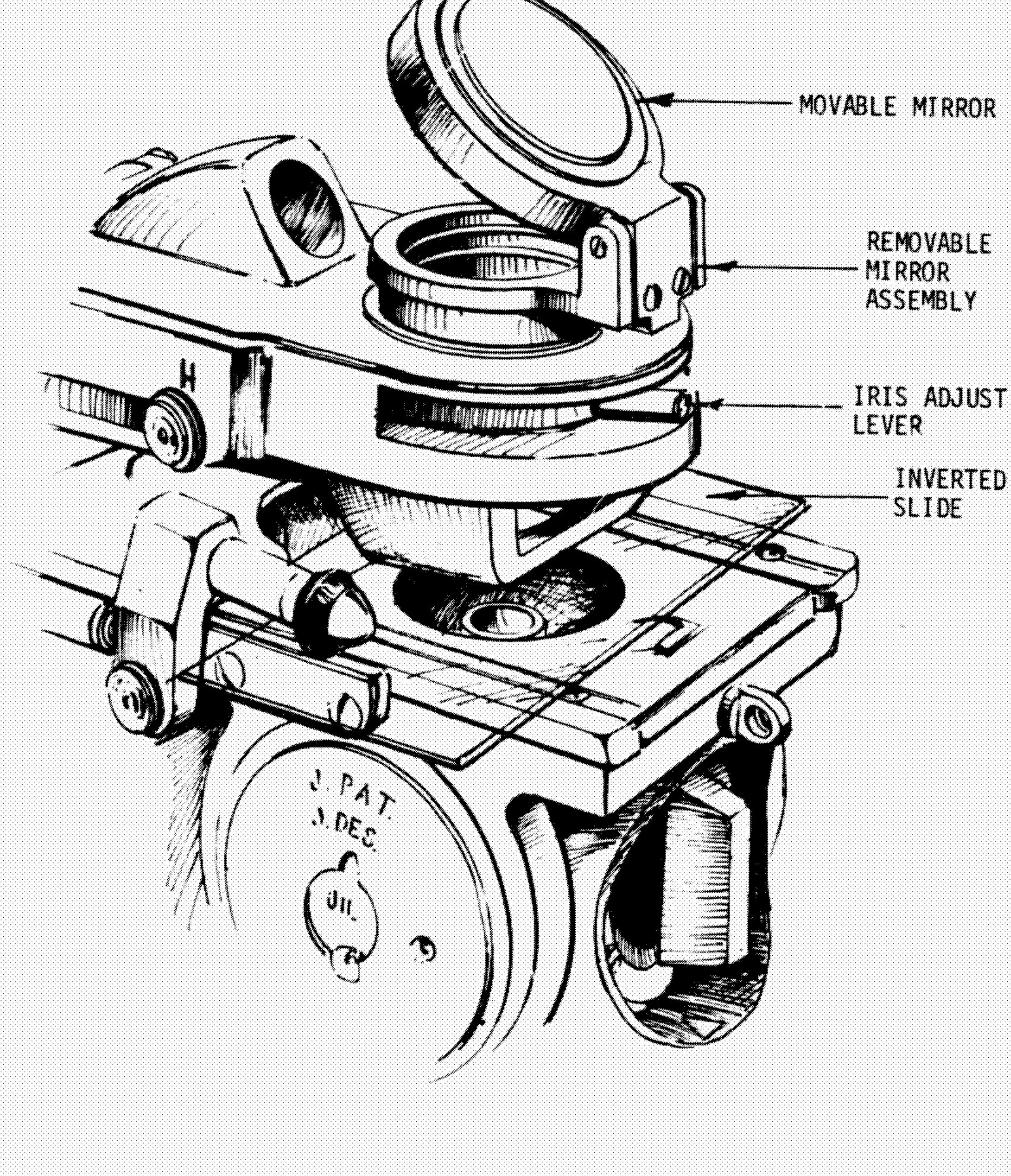


FIGURE VI-18. DETAIL OF MICROSCOPE STAGE

G. Experiment ED72 - Capillary Study

The Student Investigator for ED72 is Roger Johnston, Alexander Ramsey High School, St. Paul, Minnesota. He was assisted by a NASA Science Advisor. The hardware was designed & built by MSFC.

1. Experiment Description. Capillarity is the rise of liquids in small diameter tubes as a result of surface tension. A concave meniscus is formed when a small diameter tube is dipped into a liquid which wets the tube walls. The adhesion of the solid material and liquid interface being equal and opposite to the surface tension of the liquid results in a vertical force component which pulls the liquid upward into the tube. The liquid rises until an equilibrium state exists between the upward surface tension force and the downward gravitational force. This rise, h, can be expressed as:

$$h = \frac{2\ T \cos\theta}{r\ d\ g}$$

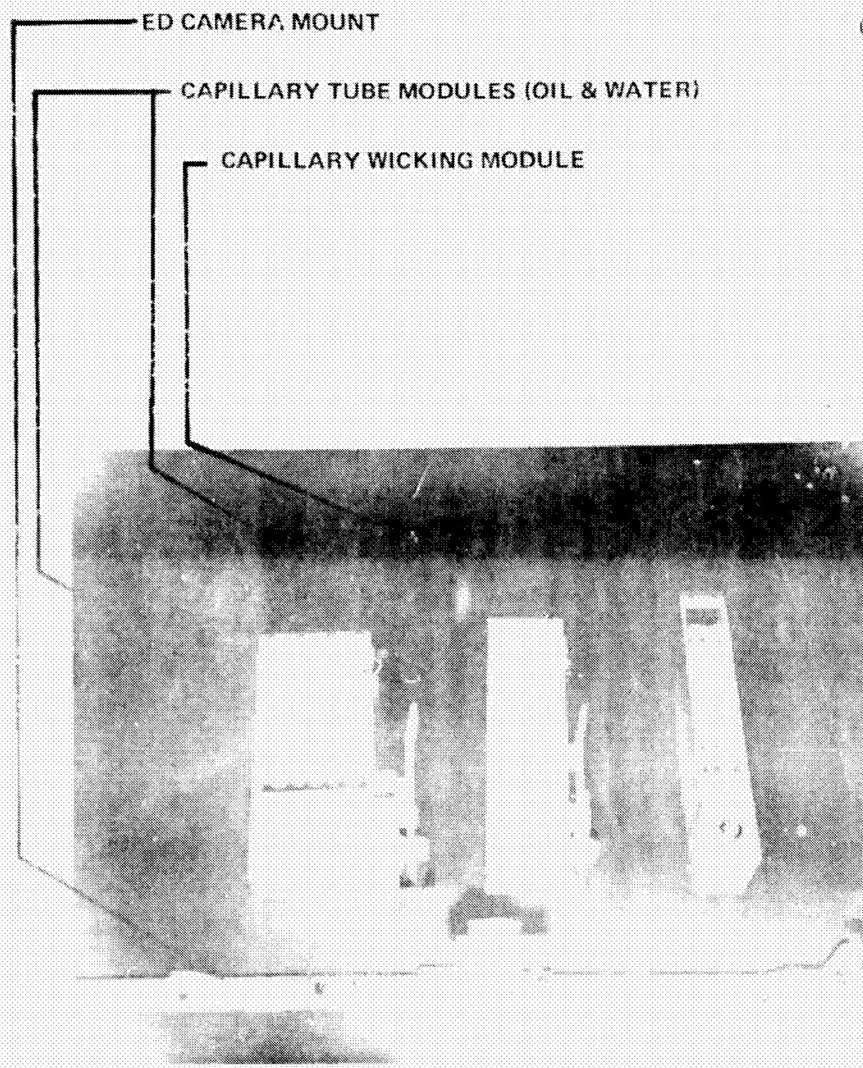
where T is the surface tension, θ the angle between the liquid and solid interface, r the radius of the tube, d the liquid density and g the acceleration due to gravity.

The inverse relationship between height of capillary vial, h, and gravitational acceleration, g, suggests that in a zero gravity environment the capillary rise might tend to infinity.

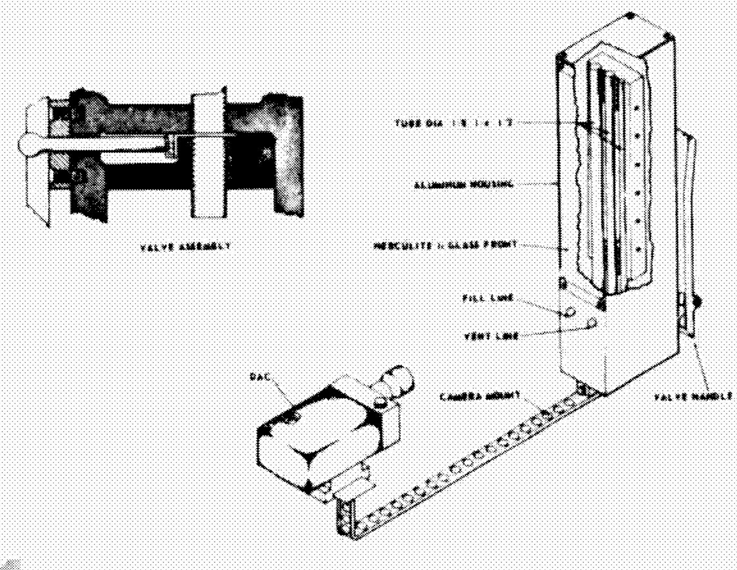
a. Objective. This experiment was to determine if a zero gravity environment induced change in capillary and wicking actions from the earth-gravity characteristics. Capillary and wicking actions could be enhanced by the elimination of gravity forces.

b. Concept. The concept was to test zero-g effects on capillary action by observation of capillary action in three hollow transparent tubes of graduated diameters using two types of liquids, and wicking action in twill and mesh screens using one liquid.

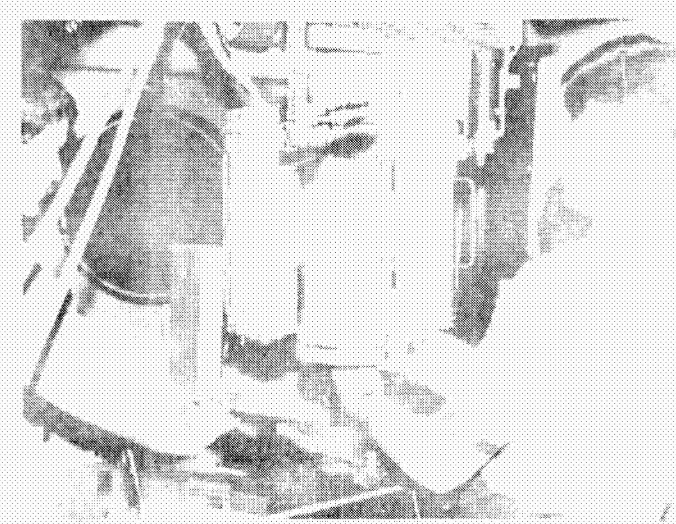
c. Hardware Description. The hardware consisted of two capillary tube modules and one capillary wick module (see figure VI-19). Experiment and support hardware and functions are listed in table VI-14. Each capillary tube module contained identical sets of three capillary tubes in graduated sizes and a fluid reservoir. One reservoir contained water and the other Krytox oil. The capillary wick module contained three capillaries of twill and mesh screens.



View of Hardware



Capillary Tube System



Simulating Deployment of Experiment

FIGURE VI-19. ED72 EXPERIMENT EQUIPMENT

TABLE VI-14 ED72 HARDWARE COMPLEMENT

Equipment	Function
Capillary tube modules (2)	Contained three tube capillaries, reservoir, and valve systems in a fixed function relationship.
Capillary wick module	Contained three wick capillaries, reservoir, and valve system in a fixed functional relationship.
Camera, DAC 16mm	Photographed experiment.
Remote control assembly, 16mm DAC	Remotely operated camera.
Lens, 18mm, for 16mm DAC	Experiment data photography.
ED camera mount	Supported camera and capillary module.
16mm film	Photographed experiment.
Portable high intensity photo light	Provided supplemental lighting to meet photography requirements.

Its reservoir contained water with a wetting agent to produce a surface tension-to-density ratio simulating liquid hydrogen. All reservoirs were force-free bladders. All fluids contained a coloring agent to enhance photographic contrast.

2. Experiment Operation. During SL-4, the entire experiment sequence was photographed beginning with the actuation of a capillary module valve and ending when the slowest fluid column reached the end of its rise.

The Pilot initiated the capillary wicking module operation on DOY 358. There was little or no wicking action for more than 2½ hours. The pilot agitated the module while moving it so the crew could eat. This apparently initiated the wicking action as reported in the voice transcript.

The two capillary tube modules, stowed behind packing board No. 13, were not immediately visible to the pilot when he removed the capillary wick module for its scheduled operation (see figure VI-20). The crew was informed that the capillary tube modules had not been exercised. An attempt was made on DOY 10 to activate the two capillary tube modules. Excessive force was required to operate the valves and once opened, the capillary tubes failed to exhibit any capillary action.

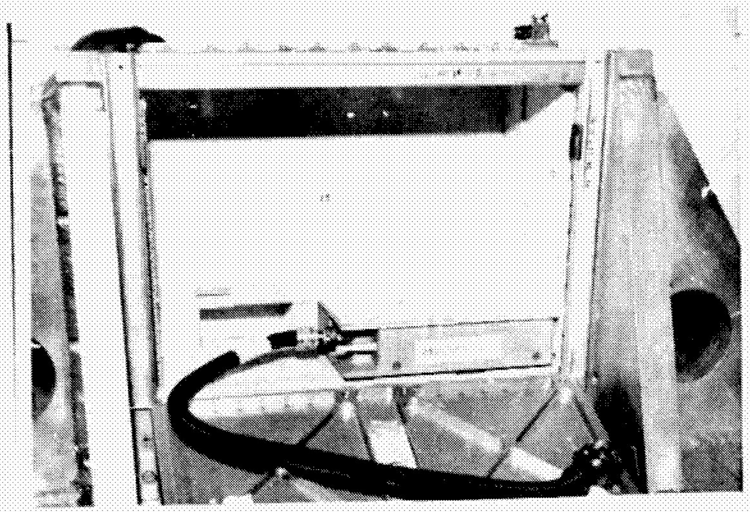
A procedure for re-filling the module fluid reservoirs was developed and submitted on DOY 015. Unfortunately the crew had disposed of the hardware before receipt of this procedure.

A second alternate procedure utilizing on-board hardware to demonstrate the capillary phenomena was developed. This was never implemented because of lack f time.

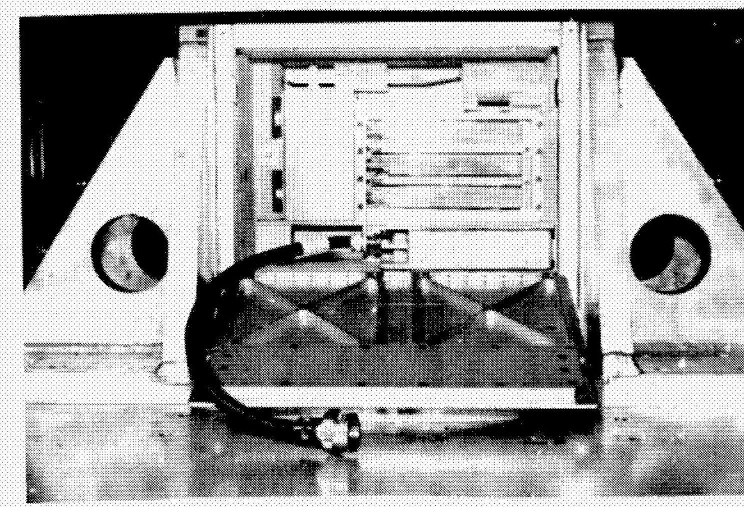
3. Experiment Constraints. All experiment constraints were successfully met during the mission.

4. Hardware Performance. The crew voice transcripts reported several hardware difficulties. Apparently all capillary liquid reservoirs leaked prior to experiment operation. These leaks resulted in an excessive force being required to operate the capillary tube valves, and a very slow wicking rate in the capillary wick module. These difficulties are discussed in paragraph 7.

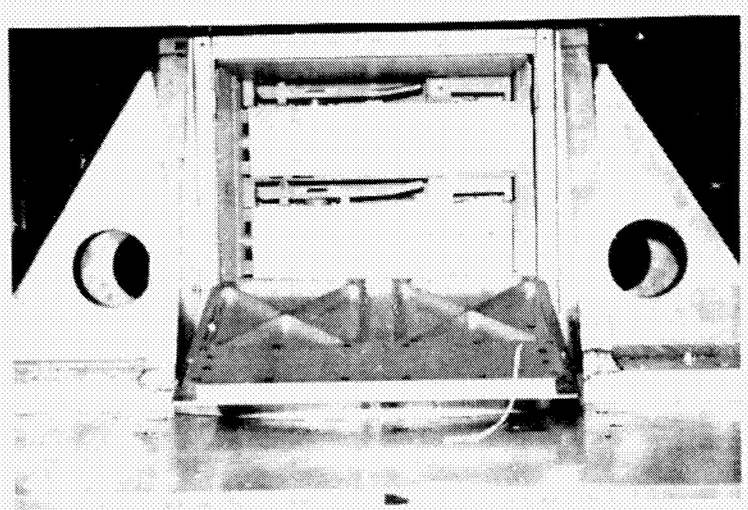
5. Experiment Interfaces. All experiment interfaces performed satisfactorily except the high temperature, low pressure environment experienced during SL-1, when temperatures reached 50.5°C (123°F) and pressures as low as 0.4 psia. Temperatures and pressures were nominal on SL-3 and SL-4 during manned and unmanned phases.



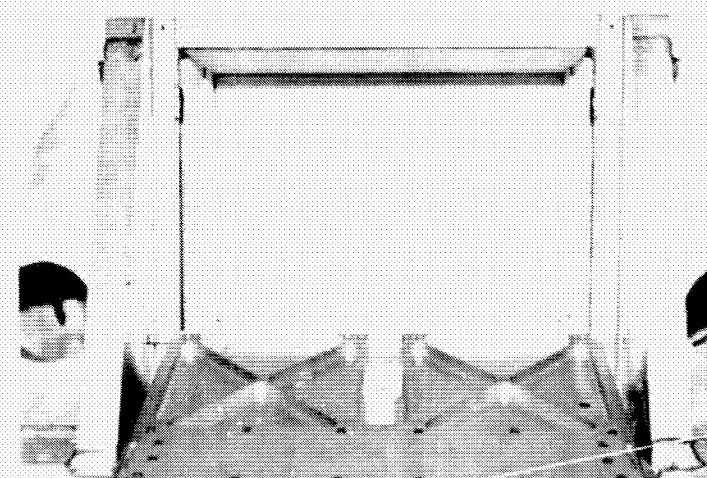
a) Wicking Module



b) Wicking Module Removed



c) Wicking Module and ED41
Motor Sensory Performance
Module Removed*



d) Capillary Tube Modules

*ED41 module removed early in SL-4 mission

FIGURE VI-20. STOWAGE SEQUENCE FOR CAPILLARY AND WICKING MODULES

6. Return Data. The return data was to be 100 feet of 16mm motion picture film, crew voice comments and the environmental parameters (bulk air temperature and pressure) at the time of performance. The data returned was approximately 25 feet of 16mm film, sketches drawn by the Pilot, and the environmental parameters.

7. Anomalies. The failure of the capillary tube modules to exhibit any capillary action and the erratic performance of the capillary wick module was attributed to the reservoirs fluid loss.

Without examination of the unavailable flight hardware, it is impossible to ascertain the cause of the fluid loss. However, water loss could be explained by boiling caused by the high temperature and low ambient pressures encountered on SL-1, (123°F). (The boiling temperature of water ranges from (72°C) at 5 psi to (12°C at 0.2 psi).) The resultant steam could have permeated the neoprene bladder, leaked around the seals, or ruptured the aluminum-to-neoprene cement bond or any combination of these failures. The oil loss cannot be explained by other than a mechanical failure of the aluminum-to-neoprene bladder seal or the neoprene bladder since the oil boiling point is 227°C at 0.2 psi. The E.I. Dupont de Nemours Co., Manufacturer of the Krytox 143AB oil, reported that this oil tested in a neoprene sealed container at 300°F for 168 hours resulted in complete oil loss from the container. A similar test at 200°F reported only minor losses. The oil reservoir failure could be caused by a launch induced vibration in the neoprene-to-aluminum bond, a degradation of the neoprene bladder itself or a combination of these or other unknown factors.

Fluid leakage at the bladder-to-case interface was a development problem and was encountered during the qualification testing. Several re-designs were made and the final design did meet the qualification test requirements, which included a pressure-vacuum cycle. The flight environment included several such cycles.

The SL-3 crew was requested to examine locker W733 for evidence of fluid leakage. The SL-3 crew examined locker W733 for evidence of fluid leakage and reported no evidence of any fluid residue. At the SL-4 crew debriefing, the SL-4 pilot reported that he had discussed this problem with the SL-3 Science Pilot. Dr. Garriott reported that he had not removed the wicking module or packing board 13 (which covers the capillary modules) from the locker (see figure VI-20). The SL-4 Pilot reported that he, too, did not observe the evidence of leakage until he removed packing board 13.

The abnormal behavior of the wicking module suggests that there was some fluid loss in this module also. If the fluid loss was sufficient, the fluid would not maintain continuous contact

with the mouth of the wick feed tube, and the result would be like that reported. Surface tension would tend to keep the fluid along the surface of the force-free bladder in the fluid reservoir away from the wick feed tube. Agitation could have resulted in fluid contact with the wick feed tube and produce the wicking action as reported.

A fluid loss in the capillary modules could have resulted in deposition of residue on the valve cores during fluid evaporation causing the reported excessive valve operating force. It is assumed that the fluid loss in the capillary tube modules was such that module agitation was not able to establish the fluid contact with the capillary tube mouth. Actual causes of the failures cannot be ascertained since the hardware was not returned for evaluation.

H. Experiment ED74 - Mass Measurement

The Student Investigator for ED74 is Vincent Converse, Harlem High School, Rockford, Illinois. He was assisted by a NASA Science Advisor. The hardware was designed and built by MSFC.

1. Experiment Description. In a zero-g environment the conventional mechanism of the measurement of weight or more correctly, mass are no longer effective. The basic means of mass determination involved either gravity or mass properties such as inertia. In a zero-g environment, only the latter means are effective. Skylab's two mass measurement devices used a spring-mass mechanical oscillator. These two devices do not provide a clear demonstration of this mass measurement principle. The ED74 free cantilevered leaf spring allows a graphic demonstration of this principle.

a. Objective. The objective was to provide a readily demonstrable method of mass measurement.

b. Concept. A simple cantilevered flexible beam (spring), loaded at the free end with several different masses, provided the means for mass determination by measurement of the mass-spring oscillator period. The period of oscillation, T, can be shown to be

$$T = 2\pi\sqrt{M/K}$$

where M is the combined spring beam mass and mass to be measured and K is the beam spring constant.

c. Hardware Description. A rectangular piece of aluminum alloy, with small cross section compared to length, was rigidly mounted at one end. Unknown or calibration masses were mounted to the free end of the beam. A strain gage was cemented to the beam near the fixed end to convert beam deflection to an electrical signal. This signal was supplied a zero crossing counter for a digital readout providing a measure of the period of beam oscillation. Tables VI-15 and VI-16 list the experiment and support hardware and the respective function. Figures VI-21 and VI-22 illustrate the hardware.

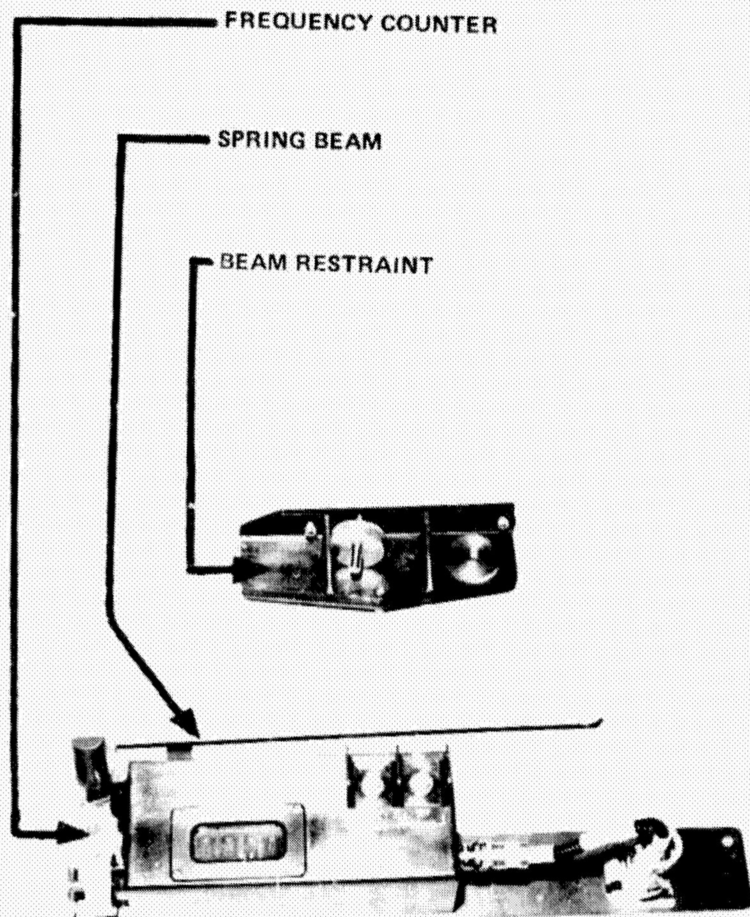
2. Experiment Operation. The operation was carried out on SL-3 with motion picture photography on DOY 239. Dr. Garriott reported that the performance was successful and no difficulties were encountered.

TABLE VI-15 ED74 EXPERIMENT HARDWARE

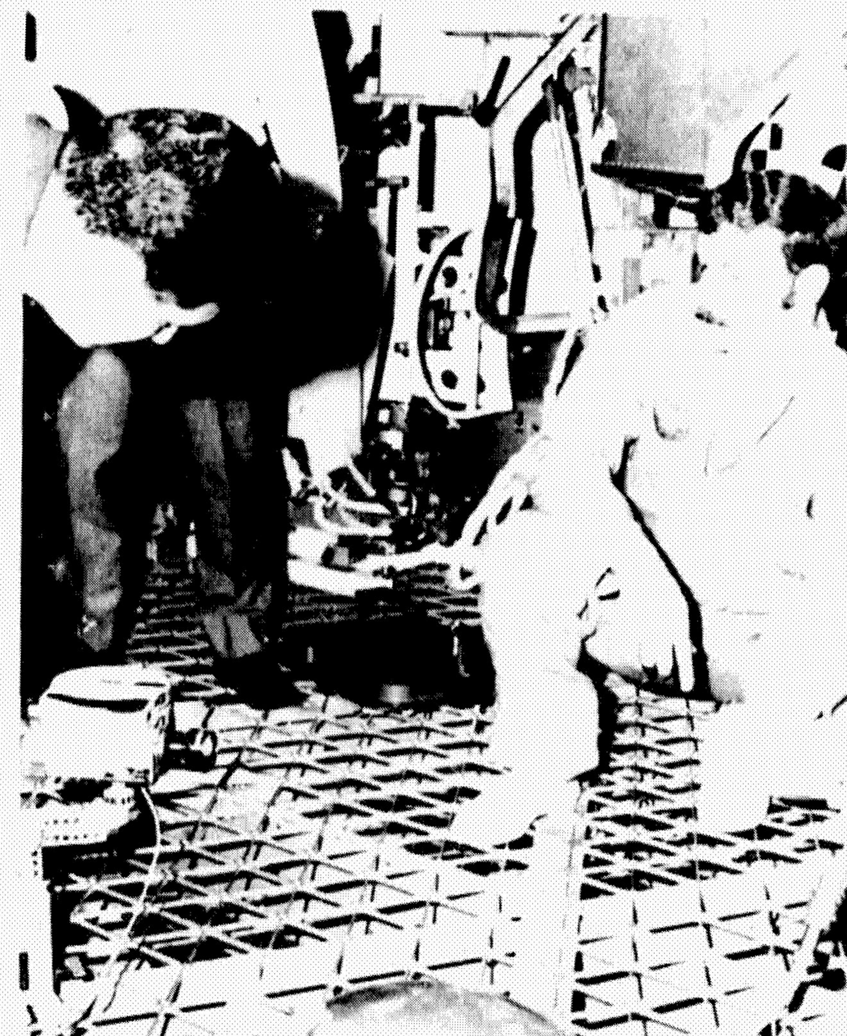
Experiment Equipment	Function
Mass measurement assembly (including Frequency Counter)	The spring beam was a simple cantilevered beam firmly attached to the frequency counter housing, which in turn was bolted to the OWS film vault. A sample holder was affixed to the free end, providing the capability of rigidly holding the masses to be measured.
Data table	The Data Table was a matrix, correlating period measurements to mass. The data were calculated by the Student Investigator, using the beam spring constant as measured on earth.
Weights (six)	Usable separately or in combination.

TABLE VI-16 ED74 SUPPORT EQUIPMENT

Experiment Equipment	Function
Data acquisition camera, (DAC), 16mm	Photograph experiment.
Remote control assembly, 16mm DAC	Remote operation of camera.
Lens, 18mm for 16mm DAC	Experiment data photography.
Universal mount	Camera support.
16mm film	Photograph experiment.
Portable high intensity photo light	Provide supplemental lighting to meet photography requirements.



View of Hardware



Simulating Deployment of Experiment

FIGURE VI-21. ED74 MASS MEASUREMENT

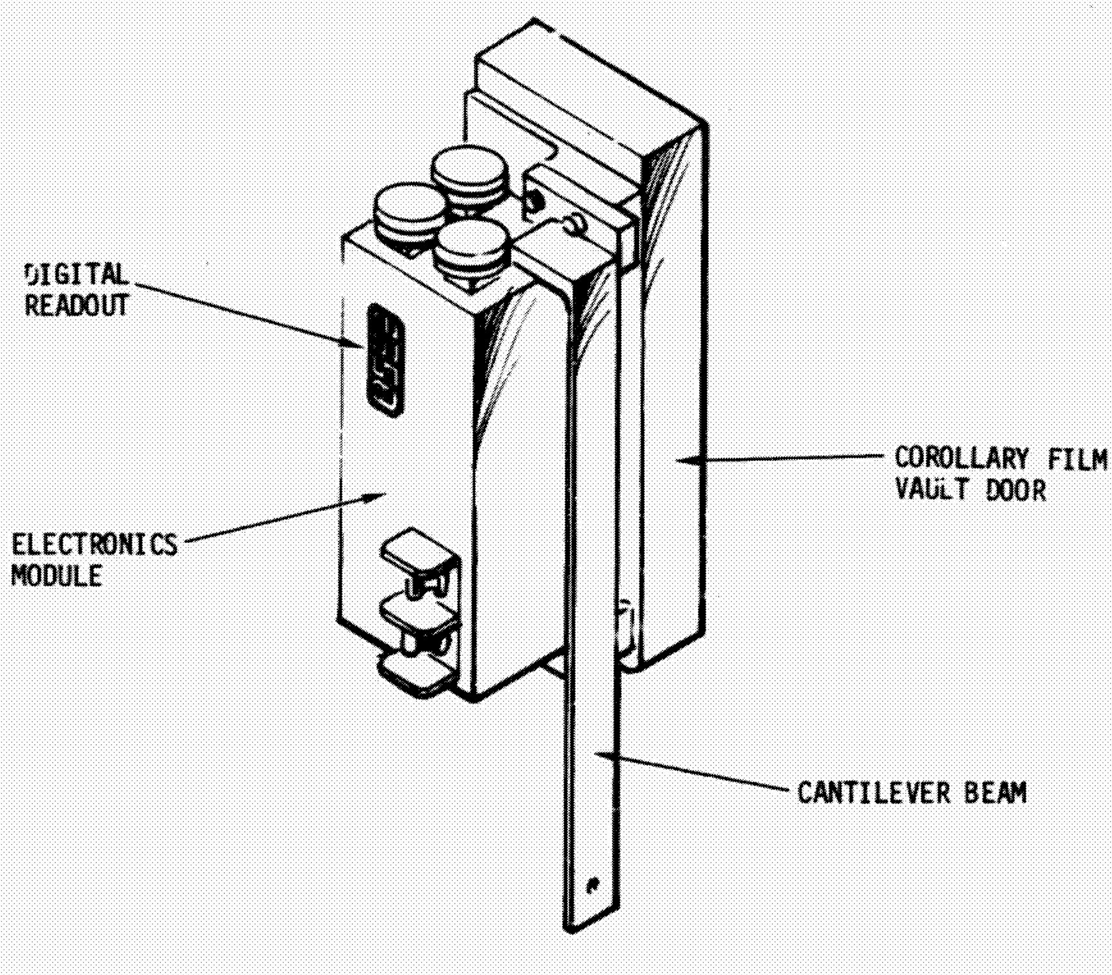


FIGURE VI-22. ED74 MASS MEASUREMENT

3. Experiment Constraints. All experiment constraints were satisfactorily met during the mission.

4. Hardware Performance. The experiment hardwarc performed as expected.

5. Experiment Interfaces. All experiment interfaces performed satisfactorily during the mission.

6. Return Data. The return data for ED74 consisted of the 16mm film, video tape converted to 16mm film and the voice transcripts. Approximately 90 feet of film was returned.

7. Anomalies. There were no reported anomalies associated with ED74.

I. Experiment ED76 - Neutron Analysis

The Student Investigator for ED76 is Terry C. Quist, Thomas Jefferson High School, San Antonio, Texas. He was assisted by a NASA Science Advisor. The hardware was designed and built by MSFC.

1. Experiment Description. The neutron in a basic element of an atom's nucleus. It is an uncharged particle with mass approximating a hydrogen atom. Free neutrons are generated by natural radioactive decay, nuclear fission, and particle collision. Neutron impingement disrupts crystal lattice structures or polymeric chains in glass, mica, and plastics. Chemical etching of these damaged structures results in patterns or tracks that are observable with a microscope. These tracks are characteristic of both the dielectric material and the impinging particles.

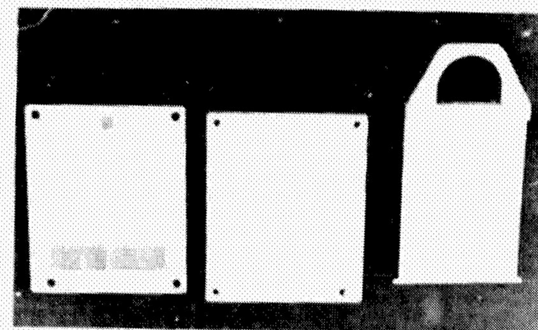
a. Objectives. The objectives were to: measure the ambient neutron flux in the OWS and identify the contributions from three sources; the earth albedo neutrons solar neutrons, and cosmic ray secondary neutrons.

b. Concept. Metallic foil and solid dielectric panel assemblies were to be selectively placed in the OWS during SL-2 and returned for laboratory analyses after exposure. The moderation effect of the OWS water storage tanks was to be investigated. Four detectors were to be returned at the end of SL-2 and the remaining detectors at the end of SL-4. Neutron sources were to be identified by selecting detector materials responsive to different neutron energy levels. Neutron impingement on boron (B) causes radioactive decay which emits alpha particles. Neutron impingement on bismuth (Bi), thorium (Th) and uranium (U) produces charged fission particles (fragments). All of these particles damage the crystal lattice structure or polymer chains in the dielectric recording media as the case may be. The returned detectors were to be chemically etched and the tracks analyzed with a microscope.

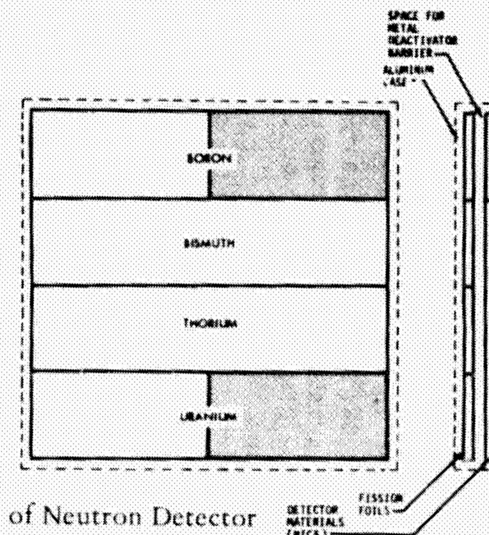
c. Hardware Description. The hardware consisted of 11 detectors with integral attachment devices, and two stowage containers for use during launch and return. The neutron detectors were aluminum housings containing a layer of foils and a layer of solid dielectric materials. The housing had a movable aluminum slide between the dielectric and the foils to prevent the fission and alpha particles from reaching the dielectric. Slide removal activated the detector. The foils consisted of uncovered panels of B-10, Bi, Th, U-235 and cadmium-covered U-235 and B-10. (See figures VI-23 through VI-26)

NEUTRON DETECTORS

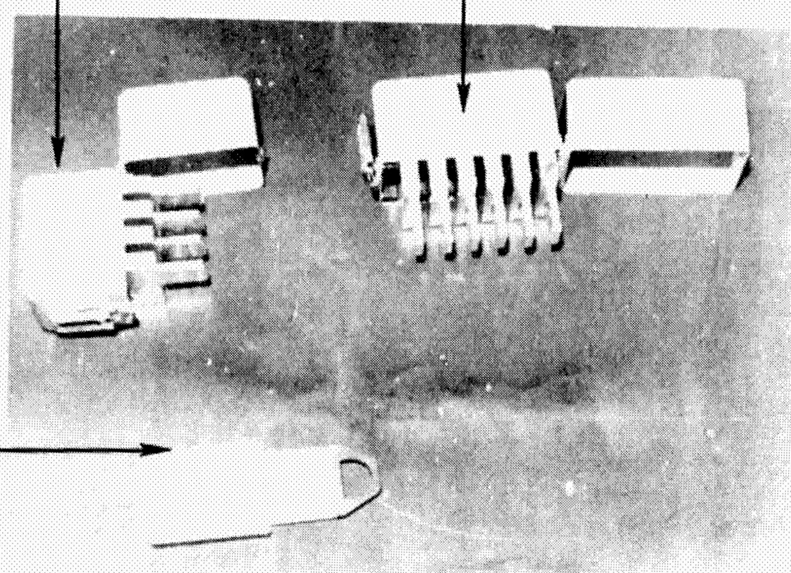
DETECTOR CARRYING CASES



Di..assembled Detector



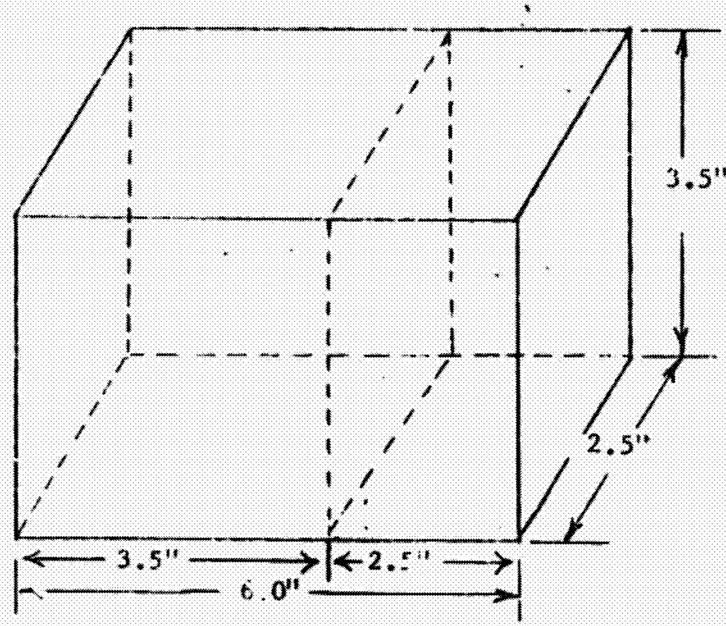
Sketch of Neutron Detector



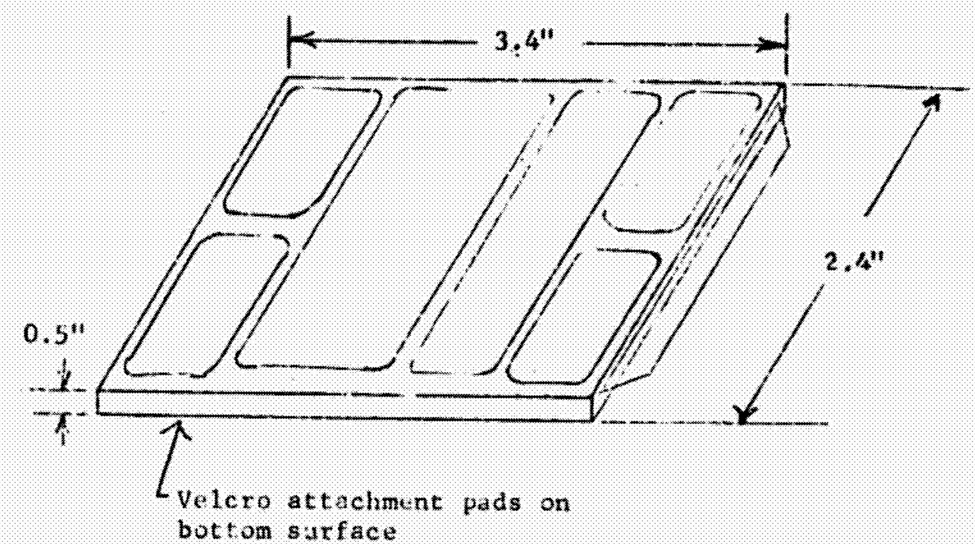
View of Hardware

Simulating Deployment of Detectors

FIGURE VI-23. ED76 EXPERIMENT EQUIPMENT



Carrying Case



Container Assembly

FIGURE VI-24. NEUTRON ANALYSIS CARRYING CASES AND CONTAINER ASSEMBLY

FIGURE VI-25. ED76 NEUTRON DETECTORS IN FLIGHT CONTAINERS

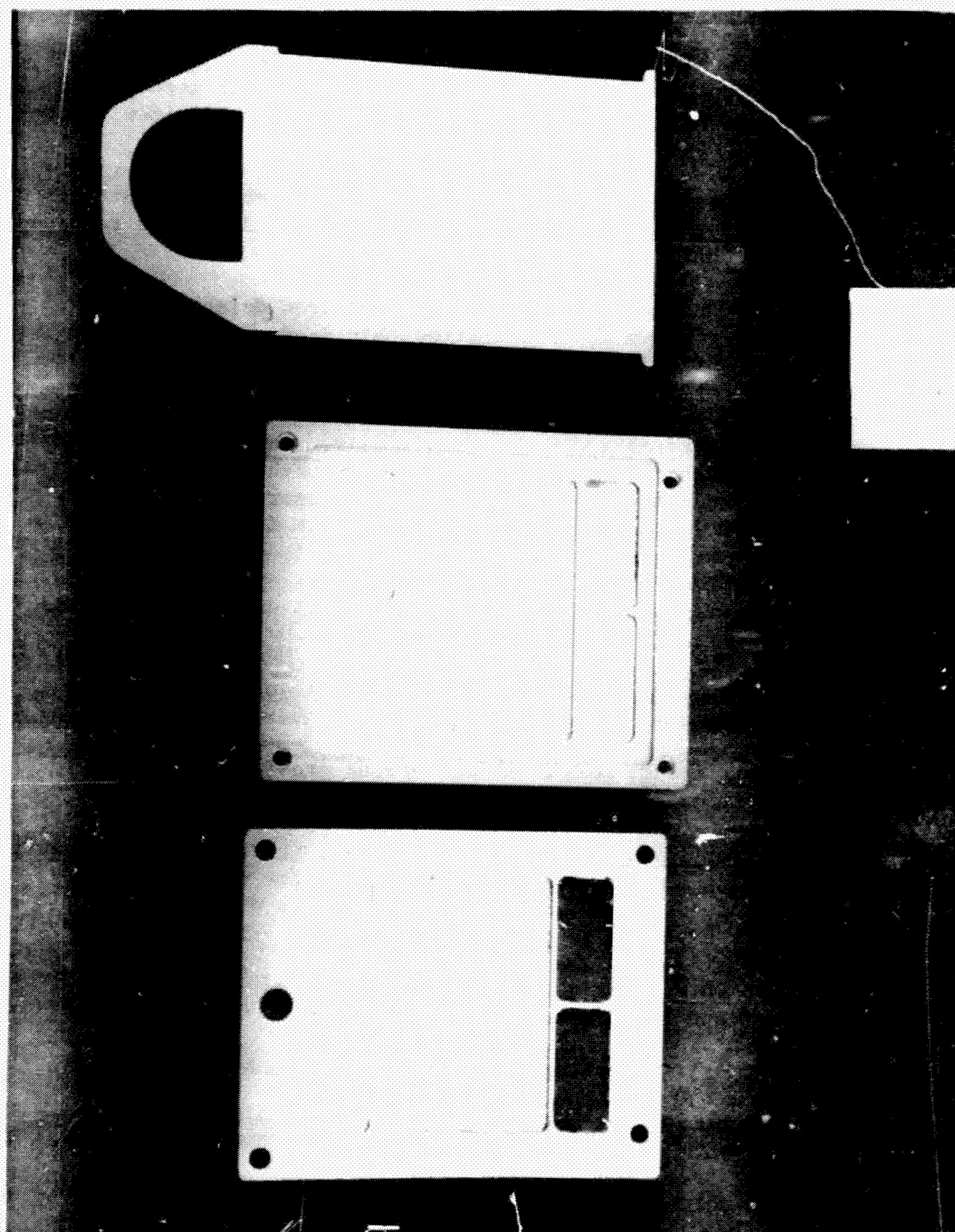


FIGURE VI-26. DISASSEMBLED DETECTOR

2. Experiment Operations. Ten detectors and two stowage containers were launched in the OWS. The detectors were removed from their containers, deployed and activated on DOY 151. Four were placed on an OWS water storage tank and six detectors at three OWS sites remote from neutron moderators (see figure VI-27).

Four detectors were deactivated on DOY 171, placed in container A and transferred to the CM for return. The other six detectors remained activated in place until SL-4 completion.

Preliminary analysis of the four SL-2 neutron detectors indicated significantly greater track densities than predicted by earlier satellite and aerometric data. Some recorded tracks were caused by proton-induced fission in the foils. Corrections were made for this phenomenon. The one detector that had been installed on the OWS water tank showed a very marked moderation effect. One returned detector was refurbished and launched on SL-4 to further study the moderation effect and evaluate the entire neutron energy spectrum. It was activated and installed in a CM locker remote from moderation effects.

The seven detectors were deactivated and all detectors returned in the CM.

3. Experiment Constraints. All experiment constraints were satisfactorily met during the mission.

4. Hardware Performance. There were no problems reported with the hardware operation.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission. The SL-4 commander commented that all crew members repeatedly placed their hands on one detector (3B) panel. This is not expected to affect the data.

6. Return Data. The return data consisted of 11 detectors, 4 returned on SL-2 and 7 returned on SL-4.

7. Anomalies. There were no anomalies in hardware operation or procedure.

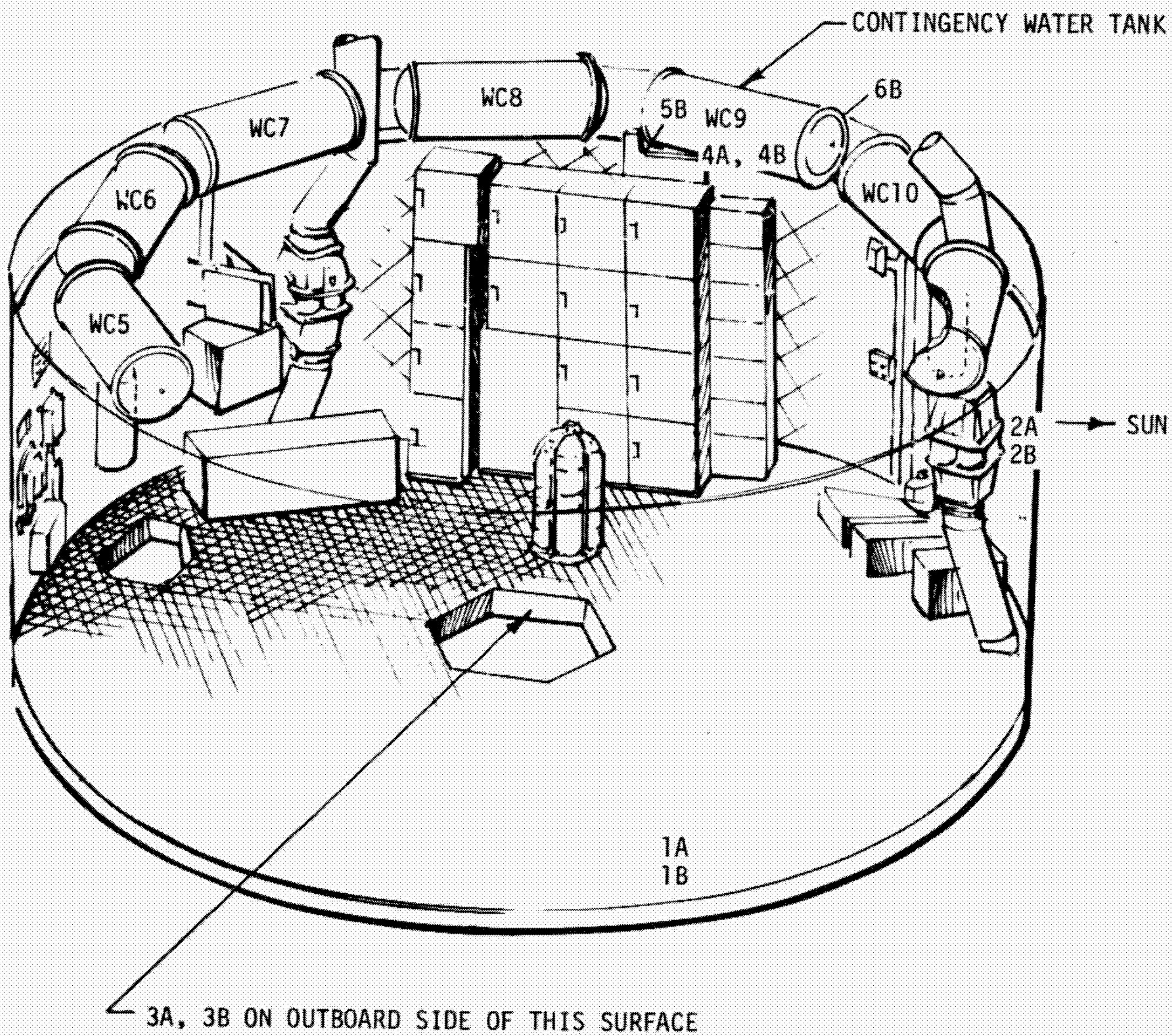


FIGURE VI-27. ED76 NEUTRON DETECTOR DEPLOYMENT CONFIGURATION

J. Experiment ED78 - Liquid Motion in Zero Gravity

The Student Investigator for Experiment ED78 is Brian Dunlap, Austintown Fitch High School, Youngstown, Ohio. He was assisted by a NASA Science Advisor. The hardware was developed and built by MSFC.

1. Experiment Description. All liquid motion is gravity dependent, especially the motion of gas bubbles in a liquid. The Skylab zero-g field presented an opportunity to study the liquid-to-gas interface motion.

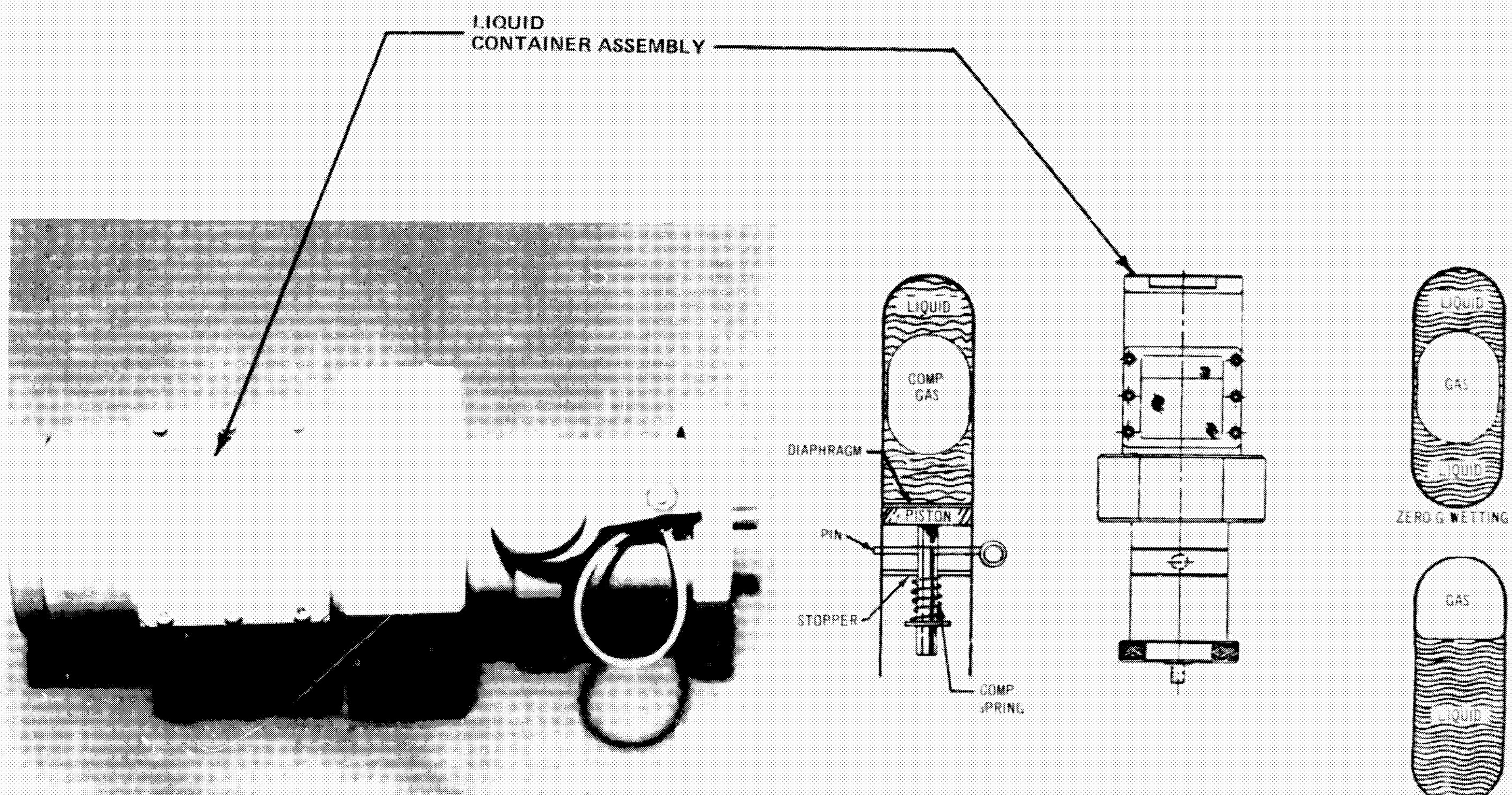
a. Objective. The objective was to observe and photograph the liquid-to-gas interface dynamic response to a psuedo-impulse in zero-g.

b. Concept. An air bubble in colored water was to be sealed in a cylinder at earth atmospheric pressure. Release of a piston, in the 5 psia atmosphere, was to provide a psuedo-impulsive force to the liquid-to-gas interface. The resultant motion was to be photographed with 100 feet of S0168 film at 24 frames per second. Crew observations were to be recorded on voice tape; if available, television was to be used. The bubble size, after expansion in the OWS atmosphere was to be less than the smallest container dimension.

c. Hardware Description. The liquid motion module consisted of two components. One was the liquid and gas chamber with a photographic viewing port sealed with an extremely flexible diaphram. The other component was the piston chamber. The piston was used to prevent diaphram expansion until manual release. Ancillary components included a jam nut to hold the two chambers together, a piston release button, a piston retention pin, a piston release block, and a camera bracket mounting stud. The gas and liquid chamber was 90% filled with colored water and 10% filled with air at earth atmospheric pressure. A nominal 10-pound pressure difference across the diaphram would exist in the OWS to expand the diaphram when the piston was released. The diaphram expansion caused by the piston release was to provide the psuedo impulsive force.

The liquid motion module and the data acquisition camera were to be mounted on the ED camera bracket. The hardware and functions are described in table VI-17 and illustrated in figure VI-28.

2. Experiment Operation. Operation was originally scheduled on SL-4 but available crew time during SL-3 resulted in adding this experiment to the SL-3 candidate list.



View of Hardware

Hardware Details

FIGURE VI-28. ED78 LIQUID MOTION EXPERIMENT HARDWARE

TABLE VI-17 ED78 EXPERIMENT HARDWARE

Experiment Equipment	Function
Liquid Container	The container enclosure for the liquid motion that is to be photographed.
Data Acquisition Camera (DAC), 16mm with 18mm lens	Photograph equipment.
ED Camera Mount	Camera Support
Portable High Intensity Photo Lamp	Lighting is required while photographing (and/or televising) the Experiment.

An attempt to perform this experiment was made on DOY 244. The science pilot reported a hardware failure resulting in no data. Repeated attempts were made to excite the oscillation of the fluid before the SPT concluded that the hardware failure was irreparable.

This hardware failure precluded further experiment operation. The failure is discussed in paragraph 7.

3. Experiment Constraints. The experiment constraints were successfully met during the mission.

4. Hardware Performance. The hardware failure is described in paragraph 7.

5. Experiment Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. No data was returned due to a hardware failure. Data from the fluid mechanics Science Demonstration (TV107) was supplied to the Student Investigator fo fulfill the objective of this experiment.

7. Anomalies. The failure of the liquid motion module was the subject of a lengthy discussion at the crew debriefing. Dr. Garriott reported that at the initial attempt to activate the piston and allow the diaphragm to expand the module appeared normal. Subsequent to this initial activation he was able to see at least a portion of the diaphragm floating up into the fluid. It appears that sometime between the SL-1 launch and the SL-3 performance the 10 pound pressure differential was dissipated and thus there was no driving force to excite the oscillations at the liquid-gas interface.

The exact cause of the failure cannot be determined witho.~ the flight hardware (which was left in orbit). The hardware was exposed to 0.2 psia during the unmanned phases of the mission. The nominal 15 psi differential pressure could have expanded the diaphragm forcing it into the 0.060 inch gap between the diaphragm retention piston and the cylinder wall resulting in diaphragm rupture and loss of pressure and fluid. No evidence exists as to the extent of fluid loss. The failure cause is undetermined.

SECTION VII. SCIENCE DEMONSTRATIONS

The seventeen science demonstrations sponsored by the George C. Marshall Space Flight Center are discussed in this section. Other science demonstrations prepared by the Lyndon B. Johnson Space Center are discussed in the Skylab Mission Reports, Second Visit (JSC-08662) and Third Visit (JSC-08963).

The need for science demonstrations (SD) became evident during the mid-portion of SL-3 when the crew repeatedly requested additional activities. The pre-mission flight plan scheduled 22 man-hours per day devoted to scientific activities. The SL-3 crew was accomplishing 28 to 30 man-hours per day after mid-mission. Experiment accomplishments soared to over 100 percent in many cases and the crew still had time to perform the two MSFC science demonstrations on DOY 263.

The MSFC was asked on DOY 242 to suggest fill-in activities that would produce useful scientific results and utilize the crews' innovative capabilities. The JSC Medical Directorate favored the science demonstrations because they provided a change of pace for the crew while producing useful scientific or educational results.

Their proposals were evaluated and procedures and support equipment defined for the most promising. Six proposals were reviewed with Dr. Parker, Skylab Mission Scientist, on DOY 260. Two demonstrations, Diffusion in Liquids and Ice Melting, were selected for implementation in the few remaining days of SL-3. These were approved on DOY 262 and performance was started during the next day.

Anticipating that the SL-4 crew would have free time, as the SL-3 crew had, 17 demonstrations were prepared for SL-4 performance. Supplies were prepared for 11 demonstrations. Supplies for seven were packaged in the SL-4 science demonstration kit, a can 4 inches in diameter by 2¼ inches high. Two demonstrations were packaged in standard large food cans. Another, the TV118 Charged Particle Mobility Device (CPMD), was launched in the Experiment ED31 food overcan. The eleventh was ten minutes of tones recorded on one of the crew's entertainment tapes for TV114, Acoustic Positioning. All the hardware except the CPMD was fabricated and assembled into flight configuration at JSC with the assistance of Mr. Charles Chassay of the Medical Directorate. Crew procedures were prepared, verified in the JSC trainer, assigned TV procedure numbers and published in Addendum A to the TV Operations Book for launch on SL-4.

The performance status of the 17 demonstrations is listed by television procedure number in table VII-1. The table includes the

TABLE VII-1. MSFC SCIENCE DEMONSTRATIONS

TV Ops No.	MRD No.	Demonstration Title	Performance Status
TV101	SD20	Liquid Floating Zone	Completed
TV102	SD19	Immiscible Liquids	Completed
TV103	SD22	Liquid Films	Completed
TV104	SD28	Gyroscope	Completed
TV105	SD33	Rochelle Salt Growth	Completed, crystal returned
TV106	SD21	Deposition of Silver Crystals	Completed
TV107	SD9	Fluid Mechanics Series	Completed
TV108	SD34	Neutron Environment	Completed, samples returned
TV110	SD30	Orbital Mechanics	Completed
TV111	SD16	Ice Melting	Performed on SL-3, not repeated on SL-4
TV112	SD17	Ice Formation	Not performed
TV113	SD18	Effervescence	Not performed
TV114	SD24	Acoustic Positioning	Not performed
TV115	SD15	Diffusion in Liquids	Performed on SL-3, not repeated on SL-4
TV116	SD23	Lens Formation	Not performed
TV117	SD35	Charged Particle Mobility	Completed
TV118	SD29	Cloud Formation	Attempted but not successfully performed

MRD SD numbers for reference. TV111 and TV115 (as SD-16 and SD-15) were performed on SL-3. Only 10 of the 17 demonstrations were performed on SL-4 because of limited crew time. One other was unsuccessfully attempted. TV109, Earth Directed Nocturnal Photography, was cancelled before SL-4 launch and is omitted from the table. Since the science demonstrations were to be extra fill-in activities, the data obtained (particularly the zero-g fluid behavior) represented a valuable bonus from the Skylab mission.

During a preflight briefing, Dr. E. Gibson, SL-4 SPT, asked that checklists be provided but stated that definition of the objectives was more important than a specific procedure because they would determine the best way to perform the demonstrations on-orbit. Since the demonstrations were left more to crew discretion than other experiments that had specific detailed test objectives and procedures, the demonstration descriptions and method of performance presented in this section are somewhat more detailed. The Principal Investigators' scientific interpretations of and conclusions drawn from the demonstration observations are documented in NASA TM X-64835 Skylab III and IV Science Demonstrations Preliminary Report.

A. TV101 - Liquid Floating Zone

The Primary Investigator for Science Demonstration TV101 (SD20) is Dr. John R. Carruthers, Bell Laboratories, Murray Hill, New Jersey. The co-investigator is Mr. Tommy C. Bannister, Space Sciences Laboratory, MSFC, Huntsville, Alabama. Dr. Carruthers provided the wetting discs, which were the only hardware launched in the SL-4 science demonstration kit for this demonstration.

1. Demonstration Description.

a. Objectives. The objectives were to examine liquid zone surface stability in low gravity under rotating conditions and axial accelerations, and to examine the liquid zone interior fluid dynamics under rotating conditions.

b. Concept. The concept was to float a liquid globule between two circular wetting surfaces that could be rotated about an axis through their centers and examine the liquid zone behavior during: rotation of the discs singly, both in the same direction, in opposite directions, and at various rotational velocities; and axial accelerations and oscillations of one or both discs. The demonstration was to be recorded with the DAC or the TV system to permit ground-based analysis of the liquid floating zone fluid dynamics.

c. Hardware Description. Operational equipment available on Skylab was used except for the wetting discs. The setup is shown in figure VII-1. Four universal mounts (UMs) were installed in coalignment on the OWS forward compartment grid floor. The 12-inch extension from the 3/8-inch socket set was mounted through holes in the camera connectors of two UMs with the large (female) end toward the other two UMs. The extension's axial position was maintained with two annular Mosite plugs that had provided launch protection to the M093 Body Temperature Measurement System probes. Similarly, the 8-inch and 4-inch extensions were connected and mounted facing the 12-inch extension. The wetting discs were attached with double-sided tape to the ends of the extension so the wetting surfaces faced each other.

Lacing twine was wrapped around the axles and attached to a pinch bar. Rotation was produced as the bar was raised and the twine unwrapped. Small strips of silver tape were placed on the extension sockets near the wetting discs to permit rotational velocity calculation.

The TV camera was mounted normal to the axis of rotation to view the liquid zone, the discs and extension sockets. A white cardboard sheet, used during launch as a spacer between the EREP tapes, provided the TV picture background. Rope particles, grape juice, strawberry drink and tea were used as tracers in the wate_ so that

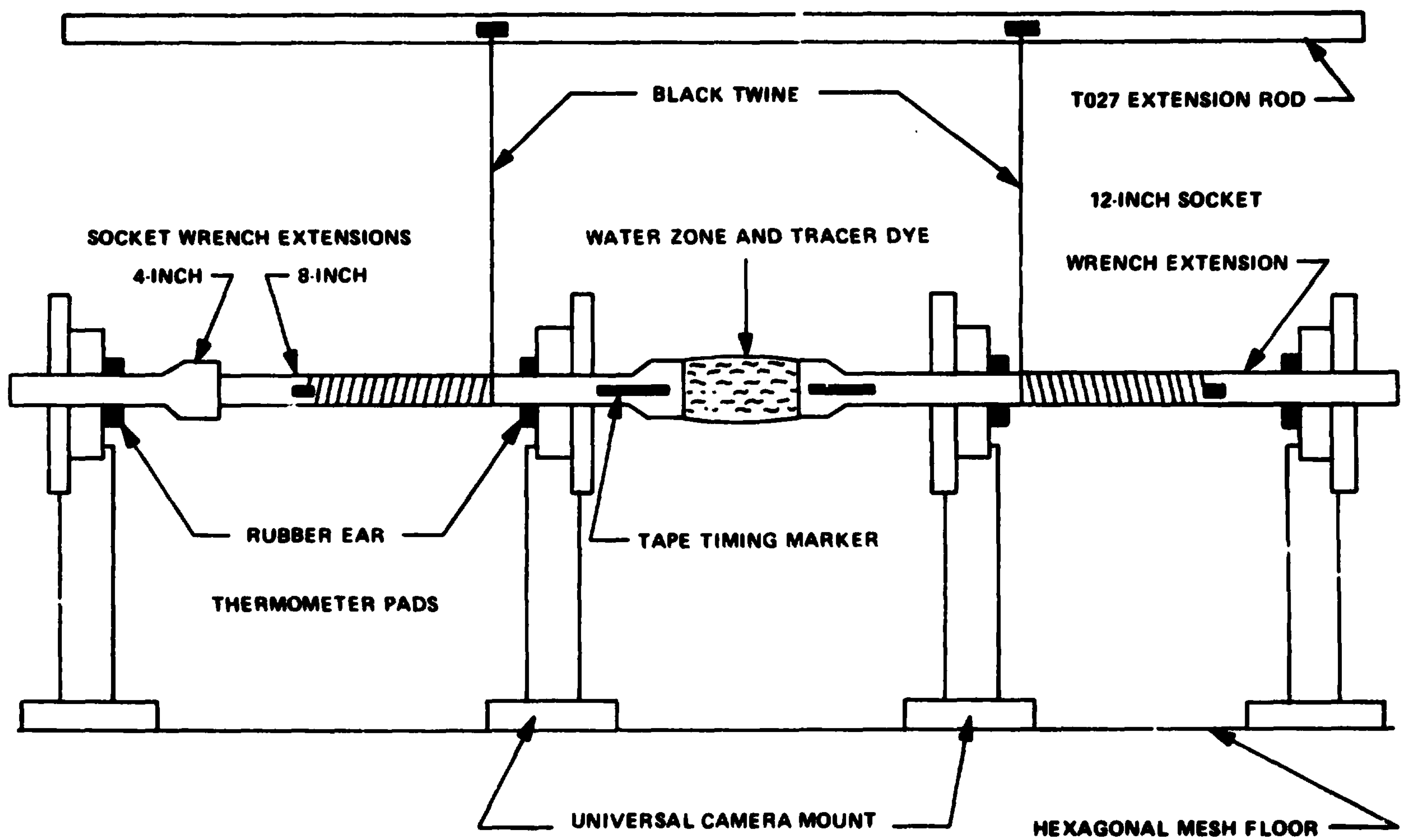


FIGURE VII-1. TV101 LIQUID FLOATING ZONE - SETUP

internal fluid motion could be observed. The portable high intensity photo lamp provided illumination.

2. Demonstration Operation. The SL-4 SPT reported on DOY 008 that the demonstration was set up and ready to start. He requested information on the DAC film availability. Since DAC film was in short supply, TV was to be used. The high TV quality resulted in no further efforts to use DAC film, although the original plan had been to use the residual film at the end of 400 ft. cassettes. The TV use permitted monitoring and adjusting the field-of-view, focus and lighting and real-time data analysis.

The first run was performed on DOY 11 and the last run completed early DOY 015. The runs are summarized sequentially in table VII-2. The parameters varied during the twenty-six runs were: the liquid zone size, the fluids used and the rotation direction. Half the total zone globule volume was attached to each disc. The rods were moved together to join the globules into a single liquid zone and the separation adjusted to form a cylinder (constant diameter) at the distance listed in the table. Most runs involved fresh fluid. Instabilities developed and the rotation was stopped during a number of runs. The run was continued when motion had damped out. These runs have two, three and more rotation sequences before the twine was unwound from the axles. The time listed in the table for each run is the time that the first rotation was started. Oscillations that were set up by the SPT, both in the individual globules before joining, and in the zone are identified in the remarks column of the table.

The TV recording of runs 10 through 15 was not accomplished and this data was lost. This anomaly is discussed in paragraph 7.

Actual rotational velocity will be determined from the TV tapes. The SPT attempted to produce a constant rate during each sequence. For the initial runs, he tried to maintain the rate requested in the checklist (16 inches in 10 seconds). After observing instabilities, the SPT generally made the first sequence in a run at a lower rate, then increased the rate in later sequences, to the limit imposed by zone instability. Fluid zones containing soap or bubbles or both went unstable or separated at lower rates than water zones.

The most common instability observed was the liquid zone taking on a jump rope (one half cycle) shape that swung around the axis of rotation. This instability occurred at lower rates for the larger liquid zones. During run 4, the SPT observed a different shape as S shaped (full cycle). However, this mode of instability quickly changed to the jump rope shape each time it was observed. The SPT felt that, in part, the instabilities encountered might have resulted from disc misalignment.

TABLE VII-2. TV101 LIQUID FLOATING ZONE - RUN SUMMARY
(BASED ON CREW TRANSCRIPTS)

RUN	DOY/GMT	ZONE SIZE VOL. (CC)	SEP. (IN)	DISC ROTATION	REMARKS
1	011/1818	6	5/8	Same	Oscillated before joining & after rotation; zone separation.
2	011/1834	6	5/8	Same	
3	011/1850	6	5/8	Counter	
4	011/1856	6	5/8		
5	011/1951	14	1 3/8	Same	Oscillated before joining; 2 instability modes during rotation; zone osc. & separation
6	011/1959	14	1 3/8	Same	
	Realigned Rods				
7	012/0132	14	1 3/8	Counter	Zone oscillation
8	012/0220	20	2	Same	Oscillated one side before joining; "jump rope" instability during rotation; zone oscillation
9	012/0250	20	2	Counter	Noted that discs not parallel; zone oscillated & stretched after rotation (necked down assymetrically).
	Removed & Remounted Discs to Improve Alignment - Krytox on Disc Edges				
10	012/1908	6	5/8	Left Side	Increased length of string to get more rotation; separated during rotation. Runs 10 thru 15 lost due to another TV input station being left on while the SPT thought he was recording.
11	Unknown	14	1 3/8	Left Side	
12	012/2355	20	2	Left Side	
13	013/0134	20	2	Same	
14	013/0154	20	2	Counter	
15	013/0221	20	2	Same	

TABLE VII-2. TV101 LIQUID FLOATING ZONE - RUN SUMMARY (BASED ON CREW TRANSCRIPTS) (CONTINUED)

RUN	DOY/GMT	ZONE SIZE VOL. (CC)	ZONE SIZE SEP. (IN)	DISC ROTATION	REMARKS
	Removed & Remounted Discs to Improve Alignment - Krytox on Disc Edges				
16	013/2113	2[illegible]	2	One Side	
17	013/2140	14	1 3/8	One Side	
18	013/2157	6	5/8	One Side	
19	014/0208	14	1 3/8	Same	Baseline for subsequent runs
20	014/0222	14	1 3/8	Same	Bubbles coalesced & moved to axis of rotation due to artificial "g"
21	014/0240	14	1 3/8	Same	Ice went to axis of rotation
22	014/1735	14	1 3/8	Same	Observed internal fluid motion during axial oscillations
23	014/1739	14	1 3/8	One Side	
24	014/2121	14	1 3/8	--	Oscillations before joining-frequency of water soap, soap damped out quicker;
				Same	Instability develops at lower rates.
				Rt Side	Soap side of zone sheared off at low rates while water side not rotated.
25	015/ 0034	14	1 3/8	--	Oscillations difficult to set up-fluid absorbed pulses.
				Same	Bubbles moved to axis of rotation.
				One Side	
26	015/0224	14	1 3/8	--	Oscillated before joining.
				Counter	Formed a Mushroom.
				Left Side	Formed a Mushroom; observed radial & axial oscillation modes.

The camera mounts were adjusted before run 7 to improve alignment. The discs were removed and remounted after the ninth and fifteenth runs in an effort to achieve coalignment of the axes of rotation and parallelism of the discs. The SPT was satisfied that the last realignment was as close as he could achieve.

The SPT observed at times that the disc edges were being wetted, distoring the liquid zone shape. He felt that this asymmetry might have contributed to instability. To control this effect, Krytox grease was applied to the discs' edges when they were remounted after the ninth run. All subsequent runs had Krytox on the disc edges. The SPT noted that he had uniform coating after remounting the discs following the fifteenth run.

The liquid zone characteristics when stretched to the point of separation were observed in several runs. At the end of run 5, the discs were separated, causing the water zone to assume an hour glass shape. At the end of run 9, the water zone was stretched but it necked down asymmetrically because one of the disc edges was wetted during rotation. The SPT observed zone separation caused by rotation, rather than zone stretching. This occurred during the runs in which only one disc was rotated (runs 12, 16, 17 and 18). The SPT observed that the zone "always tends to neck down so that the larger amount of fluid is on the rotating rod".

Artificial gravitational field effects due to centrifugal force in the rotating liquid zones were demonstrated in the runs with suspended air bubbles. The bubbles migrated to the axis of rotation. Similarly, the ice suspended in the run 21 liquid zone was centered on the axis of rotation during zone rotation.

Circulation was observed when the liquid zone for run 22 was oscillated axially. Rope particles were suspended in the liquid zone to make internal fluid motion visible. The SPT observed that the fluid moved in one direction on the outside and returned in the opposite direction through the liquid zone center with the oscillatory input from one side. The SPT reversed the circulation by oscillatory input from the other side.

The soap solutions (runs 24, 25 and 26) demonstrated the effects of reduced surface tension and increased viscosity. Oscillation frequency of the water globule on the left disc (run 24) was observed to be greater than that of the soap solution on the right disc. Oscillations in the soap solution damped out much more quickly than in the water. Rotational motion in the mixed water/soap zone was observed to damp out much more quickly than in previous water zones. Instability developed at lower rotation rates as a result of the reduced surface tension. The soapy liquid zone sheared off abruptly when only one disc was rotated.

3. Constraints. The demonstration constraints were successfully met during the mission.

4. Hardware Performance. The hardware generally performed as expected. The SPT reported, however, that he "actually had to go in and chip away paint from the holes in three universal mount supports in order to fit the extension rods through them, and then file them down." He "had to put Krytox in there so that it would turn at all, turn smoothly". No comparable tight fit had been encountered when the hardware for this demonstration was installed in the JSC trainer. The difference may be attributable to the greater usage experienced by the trainer universal mounts.

Although the SPT felt it was necessary to realign the hardware on three occasions, this is not surprising since no alignment aids were available. Visual alignment of the rods in each pair of adjustable universal mounts introduced potential errors in both axis direction and location. The centering of each disc on each rod was visual. The SPT achieved very good alignment considering the potential for errors.

5. Demonstration Interfaces. The demonstration interfaces performed satisfactorily during the mission.

6. Return Data. All the data was returned in recorded TV transmissions and voice transcripts.

7. Anomalies. The only anomaly that occurred was the loss on recorded TV for runs 10 through 15. The SPT described the loss on DOY 013, 1652 GMT: "I put in around three hours of work here yesterday on TV101 and that's all blown right down the drain because the video tape recorder (VTR) wasn't switched at the first input station, because it was turned on earlier that day and not turned of - - - you can call it human error if you like, but it's just too darn many frapping switches to check." He recommended that "first what we need at each of the TV stations is a light that comes on that says data is going on the tape and second, you need a control for the VTR right next to the input stations." The video data time lost was 15 minutes but the SPT also lost all the preparation time associated with these runs.

B. TV102 - Immiscible Liquids

The Primary Investigator for TV102 (SD19) is Dr. Lewis Lacy, Space Sciences Laboratory, MSFC, Huntsville, Alabama. Co-investigators are Dr. Guenther Otto, Physics Department, University of Alabama in Huntsville, Huntsville, Alabama, and Mr. I. C. Yates, Process Engineering Laboratory, MSFC, Huntsville, Alabama. Hardware for this demonstration was developed by MSFC, Huntsville, Alabama and packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description.

a. Objectives. The objectives were to demonstrate immiscible liquids' behavior in zero-g and determine their times of coalescence.

b. Concept. The concept was to mix immiscible liquids (clear oil and colored water) in three concentrations, observe and photograph their coalescence for 24 hours.

c. Hardware Description. The immiscible liquids were contained in three transparent polycarbonate vials. The vials were filled 25, 50 and 75 percent full of a transparent oil (Krytox 143 AZ). The remaining volume was filled with water, colored reddish orange with recorder ink. A small brass nut was included in each vial to mix the liquids when the vials were shaken in zero-g.

The vials were assembled in a frame so that they could be shaken and photographed simultaneously. The frame base was partially removable to permit assembly on-orbit. A card with diagonal lines was mounted in the frame back to permit determination of the mixed liquids concentration from the photographs. Instructions for assembling the card and vials into the frame were typed on the card back. A string was tied to the frame top permitting centrifugal separation of the liquids by swinging the entire assembly. (See Figure VII-2.)

Handheld data photographs were taken with the 35mm Nikon camera using a 55mm lens and the E2 extension tube in ambient lighting. These photographs were underexposed as an apparent result of low ambient light levels and improper exposure settings. Although underexposed, they are expected to yield useful data by using densitometric scanning techniques. The television camera with closeup lens was used to document the demonstration.

2. Demonstration Operation. The demonstration was assembled discussed and performed on TV by PLT Pogue at approximately 1300 GMT, DOY 003. The PLT reported at 1442 GMT that the initial operations had been completed. After assembling the frame with the card and all three vials, he recorded several minutes of TV. First, he demonstrated the centrifuge technique of separating the liquids and showed the

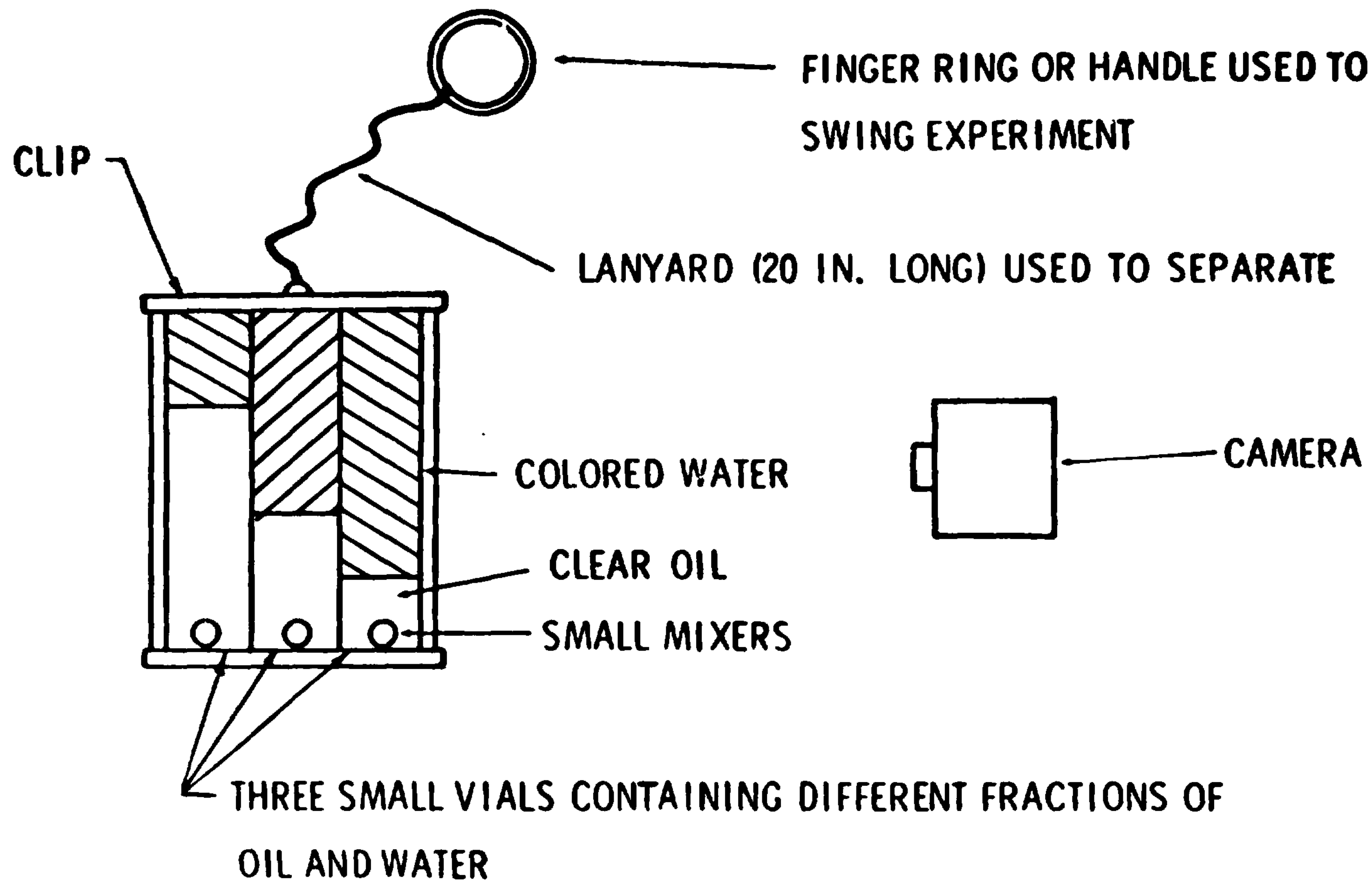


FIGURE VII-2. TV102 IMMISCIBLE LIQUIDS ASSEMBLY

boundaries between the liquids. Then he shook the assembly and showed closeups of the mixed liquids. The liquids were shaken again and the assembly mounted on the lower right corner of wardroom locker W718 for the long-term coalescence photographs.

When the PLT recorded the demonstration on TV he did not have time to narrate it. When questioned later by CAPCOM (DOY 004 at 1201 GMT), the PLT said he would do the narration after the mission.

Nikon 35mm photographs were taken at increasing intervals for approximately ten hours. Three photographs were taken at approximately 30-second intervals, five at two-minute intervals, and one each at the end of approximately 1, 2, 5 and 10 hours. The original plan was to take the final photograph after 24 hours, but a conflict developed in the use of Nikon 03 and a decision was made to terminate the coalescent photographs after 10 hours. The last frame was used to photograph the separated liquids after centrifuging. This photograph should provide a baseline for determining the concentration of the mixtures from color variations in the coalescence photographs.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The hardware performed as expected. A ¼-inch diameter bubble was present in the center vial (25 percent oil) but was a result of the vial loading on the ground and presented no significant problem to the demonstration. The Nikon camera presented no operational problems although the photographs were poor, as discussed in paragraph 2.

5. Interfaces. The experiment interfaces performed satisfactorily during the mission.

6. Return Data. The return data were the 35mm photographs, video recordings and verbal comments.

7. Anomalies. There were no anomalies encountered in performing this demonstration.

C. TV103 - Liquid Films

The Investigator for Science Demonstration, TV103 (SD22) is Mr. Wesley Darbro, Space Sciences Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description.

a. Objectives. The objective was to form liquid films in zero-g and observe their lifetime.

b. Concept. The concept was first, to form a liquid film by enlarging a fluid globule until it became a thin film. The second concept was to form films in planar and three-dimensional wire frames by jerking the frame from a fluid solution. The crewman was to make the frames on orbit, prepare water and soap solutions, observe and photograph film characteristics, with particular emphasis on film lifetime.

c. Hardware Description. The basic hardware was safety wire from the Skylab tool kit that was bent into the following configurations (see figure VII-3).

1) An expandable loop made like a lasso from 15 inches of wire.

2) A hoop about 1-inch in diameter.

3) An expandable rectangle made by sliding a wire up a U-shaped frame.

4) An equilateral tetrahedron.

5) A cube.

The demonstration used water, and a 40-to-1 liquid shower soap and water solution as the fluids. The 40-to-1 solution was used to produce an acceptable rupture time. A syringe was used to place a liquid globule on the wire loop and a used food can was the container for frame immersion in the liquids. The TV system was used to document the demonstrations.

2. Demonstration Operation. CDR Carr started bending the wires into the shapes required for this demonstration on DOY 005. He estimated that "it's going to take a good hour and a half - - - just to get the equipment built and ready to go." On DOY 009 he reported that he had "TV103 ready to go" whenever VTR time was available. On DOY 011 CAPCOM offered the CDR VTR time but the CDR said he needed more practice and that he "really didn't have all the little

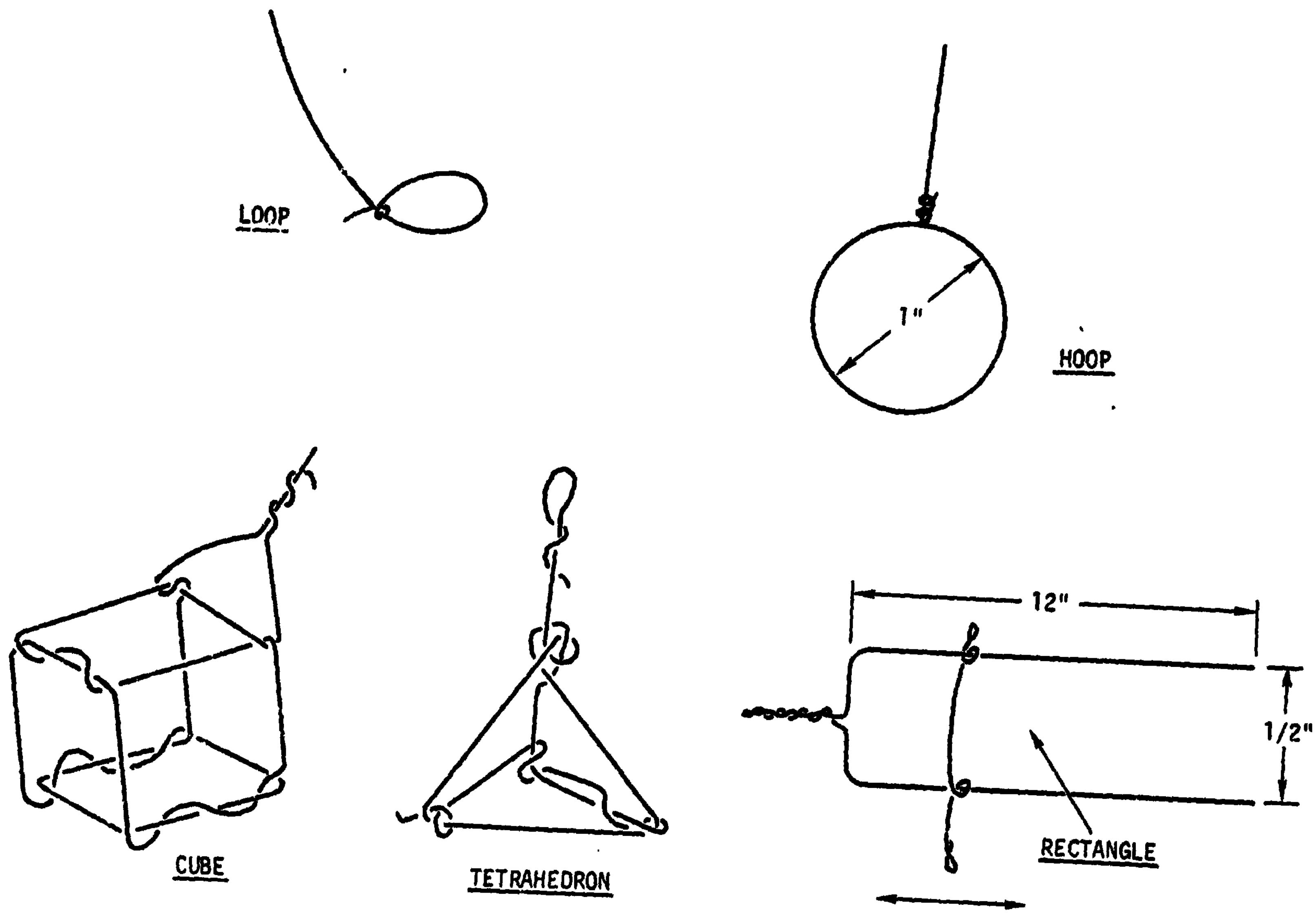


FIGURE VII-3. TV103 LIQUID FILM WIRE FRAMES

wire goodies made yet." On DOY 013 the CDR requested more "background information about TV103 and what some of the correlations are." The Investigator prepared additional information on his thin film rupture research and the differences between one-g and zero-g film rupture. This information was sent as a teleprinter message.

The CDR practiced the demonstration at various unscheduled times until on DOY 024 at 2119 GMT he started the TV demonstration. He performed several runs of each film formation technique in a continuous sequence until the demonstration was completed at 2210 GMT on the same day. He reported later that he would like to repeat some runs with the closeup lens on the TV but on DOY 029 at 0120 GMT CAPCOM suggested that the crew move on to some other science demonstrations and come back to TV103 later, if time permitted.

The CDR's observations during the performance and the crew debriefing follow. He made the general comment that his practice sessions were better than the runs he got on video tape. It is suspected that the wire may have been accidently contaminated with residual soap by the time he performed the runs for the TV.

The loop with plain water could be expanded to 1.5 to 2 inches in diameter. With a solution the loop could be expanded to about 6 to 6.5 inches. He used one cc of fluid in each run with the loop. With the solution, the CDR reported having some difficulty transferring the fluid from the syringe to the loop or the rectangle.

The CDR taped one sequence with the sliding rectangle using about 1/8 cc. He was able to stretch the rectangle to about seven inches before the film ruptured. It is not known which fluid was used. A comparison run was not recorded on the VTR. The CDR commented, however, that the sliding rectangle was "a much more controlled method of drawing out a film" and that he could "keep redrawing the thin film" by moving the slide wire back to the base of the U.

With the three frames (loop, cube and tetrahedron), the jerk technique of pulling the frame from the fluid resulted in spilling part of the liquid. Slow removal worked better, but carried some liquid with the frame. Excess fluid was removed by shaking the frames, leaving thin films. All the video taped runs with the frames used a solution retained in a used food can.

The three dimensional frames (cube and tetrahedron) produced films that were quite short-lived. The films connected the small inner globule to each of the frame members. Whenever a very small inner globule or a no-globule configuration was achieved, the films would break rather quickly. During the TV runs they broke within a few seconds. In the debriefing, the CDR reported that he had achieved lifetimes for fully-connected films of about one minute, maximum.

When the films broke the first time in the cube, three of the six sides remained. The second break, which occurred fairly quickly, formed films on two sides which "seemed to be its most stable configuration", lasting for more than two and a half minutes.

It was more difficult to achieve a fully connected film configuration with the tetrahedron than with the cube. Based on voice transcript comments, it seemed to break down more quickly, generally forming a two-sided configuration, which would then break down having all the fluid across a single face in a thick film. The CDR described the films formed on the tetrahedron as appearing like "a line was drawn in from the vertex of each of the corners - - and it all meets in the middle."

The planar loop frame was run twice during the TV taping sequence. The longest reported lifetime was a minute and a half. The lifetime of all the films formed by the pull technique was strongly dependent on the amount of fluid retained on the frames. The CDR concluded "that the stability has to do with the amount of fluid that you can get, and the thinner the fluid film , the less stable." He further commented that "it appears to me - - that it's feasible, in zero-g, to make thin films. You can do it, rather than jerking, by shaking."

Frame handling probably contributed to shortening their lifetimes. After pulling a frame from the solution, the CDR attached the frame stem to the sticky side of a piece of tape. Attaching or removing each frame disturbed the other frames, breaking their films.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The wire frames made by the CDR were quite satisfactory. The operational support equipment (syringe and TV) performed as expected. The difficulty the CDR had in transferring the fluid from the syringe to the wire indicated that their wetting properties were nearly equal.

5. Interfaces. The demonstration interfaces performed satisfactorily during the mission.

6. Return Data. The return data were the video recordings and the verbal description. The TV coverage was fair. As the CDR suggested, it could probably have been improved considerably by using the closeup lens for much closer viewing of the films. The wardroom table top, in the background, also made it difficult to see the films.

7. Anomalies. There were no anomalies encountered in performing this demonstration.

D. TV104 - Gyroscope

The Investigator for Science Demonstration TV104 (SD28) is Mr. James Parker, Space Sciences Laboratory, MSFC, Huntsville, Alabama. The gyroscope was purchased from the Alabama Space Museum, Huntsville, Alabama and packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description.

a. Objectives. The objective was to demonstrate the behavior of a gyroscope in zero-g.

b. Concept. The concept was to spin a gyroscope wheel and, while it was spinning, discuss gyroscope uses in space technology, and demonstrate precession.

c. Hardware Description. The gyrscope was a toy version, modified as shown in figure VII-4 to suit the demonstration objectives and to meet materials and safety requirements. Since the gyroscope wheel could be suspended freely in Skylab, most of the frame was removed. A single arc of the frame was retained to provide a handle for the gyroscope whe spin up, and finger holds to bend the frame releasing the spinning wheel. A drop of Krytox oil was placed in each axle hole in the frame to reduce friction during spin up. Two 36-inch pieces of number 60 Nomex thread were included in the kit for gyroscope spin up. A loop was tied in each thread end to make it easier to pull. Soda straws were used to apply forces to the gyroscope wheel.

To meet materials safety requirements, the frame and gyroscope wheel were stripped to the bare metal. The frame was plated with electroless nickel and the wheel was flash-coated with gold.

The TV system was used to record the demonstration.

2. Demonstration Operation. On DOY 006, the CDR requested that additional information on the Skylab CMGs be teleprinted to him. He had apparently practiced TV104 and was preparing his discussion. He asked for information such as CMG wheel speed, weight and diameter to better discuss gyroscope use in controlling Skylab.

On DOY 009 at 2038 GMT, the CDR started the TV demonstration and recorded about 12 minutes of video tape. He showed the unstable motion of the non-spinning gyroscope, demonstrating that after a force was applied the gyroscope translated and tumbled. He spun up the gyroscope and demonstrated that it translated after a force was applied, but it did not tumble or drift in rotation, and that it rotated only while the torque was applied.

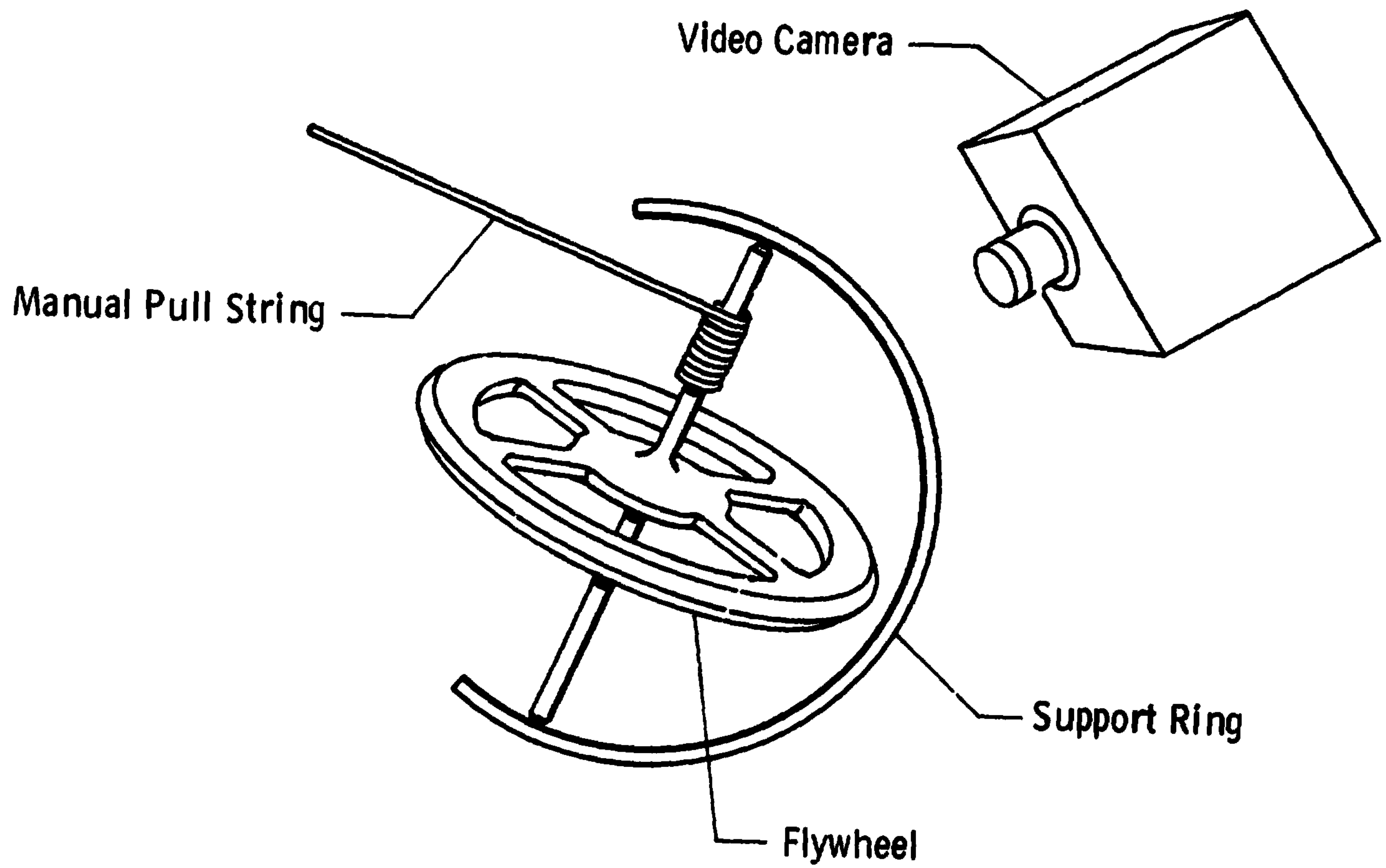


FIGURE VII-4. TV104 GYROSCOPE

Precession was demonstrated at three wheel speeds. First, at high speed, it precessed at approximately 90 degrees from the direction of the applied forces, with little wobble. At an intermediate wheel speed, a little more wobble was introduced. At very slow speed (the spokes could almost be seen going around) the resultant precession was about 20 degrees from the theoretical 90 degrees. The CDR explained this effect was "precession caused by friction" and related this and the greater stability of higher wheel speeds to practical gyroscope design for spacecraft.

The CDR related these principles to the rate gyroscopes used for Apollo and Skylab attitude reference. He explained the difference in Apollo and Skylab attitude control techniques, the use of thrusters to apply control torques to the CSM, and large CMGs used to apply control torques to Skylab. He gave some of the Skylab CMG statistics. He pointed out that the experiment M509 backpack used small gyroscopes and CMGs to provide a stable control system. The first video taping session was concluded at 2050 GMT.

After reviewing the recorded video sequence, the television group requested additional TV104 segments explaining that "usually we can edit your TV to any length we need, but we have not been able to shorten this one without destroying its value", and 12 minutes was too long for the mission summary. A teleprinter message detailing the additional scene requirements was sent at 0115 GMT on DOY 026.

At 2045 GMT on DOY 026, the CDR started a second video recording session with the PLT as cameraman. He repeated the free floating (non-spinning) and precession demonstrations, relating, in a somewhat more detailed fashion, the behavior of the toy gyroscope to Apollo and Skylab attitude control. He completed this second TV sequence at about 2110 GMT. He expressed his preference for using "the second cut of the first sequence and the first cut of the second sequence."

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The gyroscope used in this demonstration performed as anticipated. The gold color showed up well on TV. The TV system performed normally.

5. Interfaces. The demonstration interfaces performed satisfactorily during the mission.

6. Return Data. The returned data was the video recording and the voice recording.

7. Anomalies. There were no anomalies encountered.

E. TV105 - Rochelle Salt Growth

The Primary Investigator for TV105 (SD33) is Dr. I. Miyagawa of the University of Alabama at Tuscaloosa, Tuscaloosa, Alabama. The co-investigator is Mr. Tommy C. Bannister of the Space Sciences Laboratory, MSFC, Huntsville, Alabama. The Rochelle salt crystals were grown and the solution prepared by Dr. Miyagawa. They were canned at Swift and Company, Oak Brook, Illinois.

1. Demonstration Description.

a. Objectives. The objective was to grow Rochelle salt crystals by precipitation from a saturated solution. This was to be the first crystal growth in space by precipitation.

b. Concept. The concept was to heat a solution of water, a seed crystal and sacrificial crystals to approximately 150°F, and to precipitate additional material on the seed crystal by slowly cooling the mixture. The solution, seed crystal and sacrificial crystals were to be prepared to use the Skylab food tray 150°F capability.

c. Hardware Description. The Rochelle salt (sodium potassium tartrate) included a 26 gram seed crystal plus enough sacrificial crystals to maintain a saturated solution up to 160°F. Initially the seed and sacrificial crystal mixture was placed in large Skylab food cans (4-inch diameter by 1¼-inch height) with distilled water and sealed at 5 psia. Lids with membranes were used to permit the crew to visually inspect the crystals before and after precipitation.

The 35mm Nikon camera was used to photograph the crystal. The TV system was used to record the preparation and heating of the can and crystal.

2. Demonstration Operation. The Rochelle salt can was unstowed, the pull top lid removed and the can placed in a food tray to heat from 1300 to 1440 GMT on DOY 003 by the PLT. At 1201 GMT on DOY 004, the PLT reported that "the Rochelle salt is sitting in the locker per instruction, covered with wash cloths." He recorded on the VTR his preparation activities and the placing of the can in the food tray.

After allowing time for gradual cooling of the insulated can, the PLT reported at 0202 GMT on DOY 006 that: "three 35m photographs were taken. There was a nice size crystal in there; however, it was very, very difficult to get proper lighting" due to reflection off the membrane and the poor visibility of a clear crystal in a white can. He would "let it sit overnight - - and try to figure out a way of getting a photograph so that you can see the crystal." CAPCOM

later that day (1211 GMT) requested him "to leave the crystal where it is and let us take a look at our film budget before you do that."

On DOY 025 a teleprinter message was sent with instructions for breaking the membrane, draining the fluid, recording three orthogonal views of the crystal with the TV and preparing the crystal for return by wrapping it in a face cloth. The crystal was removed from the can and 35mm photographs were taken on DOY 036 or DOY 037. Discussion of the crystal growth application to space manufacturing during a TV demonstration of the crystal was not performed because of lack of time. The returned crystal arrived in good condition and was delivered for ferroelectric hysteresis analysis of crystal quality.

During the debriefing, the PLT described the crystal as a perfectly formed flat plate about 1/4 by 1 1/2 by 1 3/4 inches when it was first grown. When the crystal was removed, he said it seemed to be smaller than when the can was first unwrapped indicating the crystal had dissolved noticeably during the 20 days it remained in the solution. He noted there were still small crystals, that looked like ice cream salt, in the can when he drained the solution off.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. Experiment hardware and support equipment performed as expected. The only improvement suggested by the PLT was to paint the can interior a dark color (mat black) to enhance clear crystal visibility.

5. Interfaces. The demonstration interface performed satisfactorily during the mission.

6. Return Data. The return data was the crystal shown in figure VII-5 photographs, recorded video and crew descriptions.

7. Anomalies. There were no anomalies encountered.

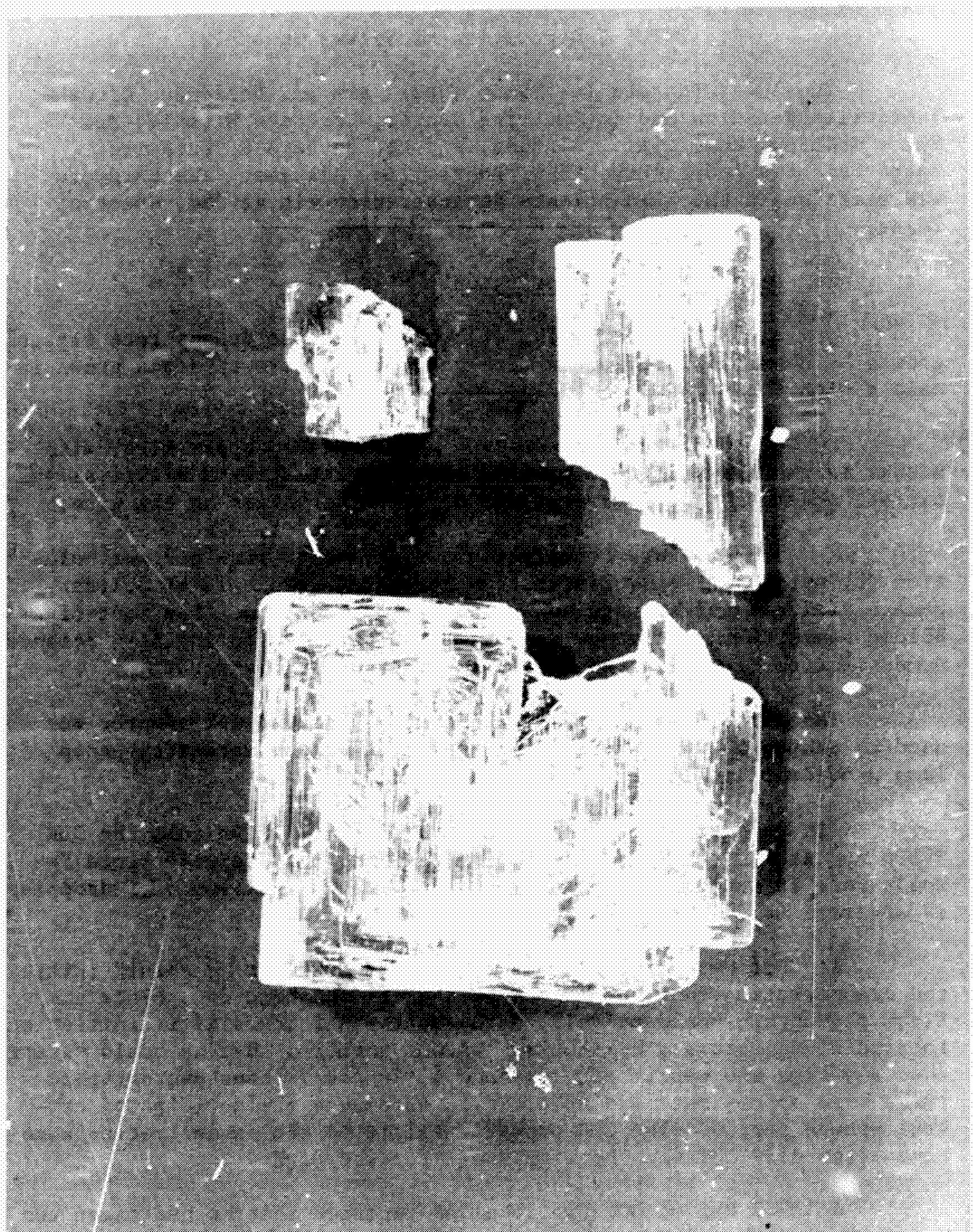


FIGURE VII-5. TV105 ROCHELLE SALT CRYSTAL

F. TV106 - Deposition of Silver Crystals

The Investigators for TV106 (SD21) are Dr. Philomena Grodzka, Huntsville Research and Engineering Center, Lockheed Missiles and Space Company, Huntsville, Alabama, and Ms. Barbara R. Facemire, Space Sciences Laboratory, MSFC, Huntsville, Alabama. The hardware was packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description.

a. Objectives. The objectives were to demonstrate crystal growth by chemical reaction in zero-g and to compare crystals grown in zero-g with those grown in one-g.

b. Concept. The concept was to place copper wire, with breaks in the insulation to provide reaction sites, in a dilute silver nitrate solution and observe growth of silver crystals on the wire.

c. Hardware Description. 9.5 ml of a five percent solution (by weight) of silver nitrate were loaded into a 10 ml polycarbonate vial and sealed with an O-ring in the vial cap. One foot of Beldon number 8051, 22 gauge copper wire was coiled in the SL-4 Science Demonstration Kit, with the silver nitrate solution vial.

The 35mm Nikon camera with the 55mm lens and K-1 adapter was used to photograph the crystals. The portable high intensity photo lamp provided illumination.

2. Demonstration Operation. On DOY 24, CAPCOM told the CDR, TV106 operator, "to change the optional TV to, not desired" since "we don't feel it would show up sufficiently well." The impact of dropping TV coverage is discussed in paragraph 7.

At 0051 GMT on DOY 025, the CDR asked whether he should initiate the demonstration that evening or wait unitl the next day, since the first photograph would be delayed to about eight hours after initiation, instead of the planned six hours. CAPCOM answered that he could "start that any time you want." The planned 6, 24 and 72 hour photographic times were approximate and selected to encompass the anticipated crystal growth period. The CDR probably initiated the demonstration sometime after 0159 GMT when he signed off for the night.

At 1307 GMT on DOY 025, the CDR reported that he had taken two Nikon photographs of the crystals, about ten hours after initiation. The photographs were both taken at f-2.8, but one at 1/30 second, as called for in the procedure, and the second at 1/60 second. The CDR was concerned that 1/30 second was too slow for hand-held photography. He noted, "the light meter that's integral with the camera indicated that we probably ought to be using an f-stop of 5.6."

The second set of photographs was scheduled in the DOY 025 flight plan at 1937 GMT. At 1515 GMT, CAPCOM requested that the CDR delay them until his presleep activities to get closer to the desired 24 hours. The CDR agreed and commented that "those crystals are really growing - .- those are really beautiful - - they seem to be forming in a pretty classical-looking lattice structure." At 0216 GMT DOY 026, he reported that he had taken two photographs, both at 1/25 second, at f-2.8 and f-4.

At 0141 GMT on DOY 027, the CDR discussed the Nikon settings, that the integral light meter indicated he should be using an f-5.6 at 1/30 second or an f-8 at 1/250 second. The portable light meter indicated an f-5.6 at 1/25 second. He suggested a faster shutter speed since the camera was handheld and he had a "high intensity light that's only two feet away from the vial." CAPCOM suggested that "we have plenty of that film, why don't you use your own judgment and bracket the f-stop and speed settings." At 0219 GMT on DOY 028, the CDR reported that he took three 35mm photographs of the crystals, two at an f-4 at 1/60 second and the third at an f-5.6 at 1/125 second, frames 65, 66, and 67 of magazine CI-115.

During the third photographic session, the CDR observed that "the most phenomenal growth rate was the first 24 hours". During the postflight debriefing, he estimated that the growth rate was a maximum between 24 and 48 hours and was all over after about 72 hours. While looking at the crystals, he said they "look like a little - - sort of a silver christmas tree down there at the bottom and then up along the copper, there's quite a few areas of rather dendritic growth". He observed that the solution had "turned sort of a light green now" (the color of copper nitrate).

OWS temperature during the crystal growth period ranged from 71 to 74°F and was 71 to 72°F during the peak growth rate period.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The hardware used for this demonstration performed as expected, except for the Nikon photography. The CDR found that camera settings different than called for in the checklist (f-2.8 at 1/30 second) were indicated by the integral light meter and the portable light meter. The principal differences between the ground tests and his setup, were his use of the high intensity light and desire to use a faster shutter speed.

5. Interfaces. The demonstration interface performed satisfactorily during the mission.

6. Return Data. The returned data were the crystals shown in figure VII-6 with crystals grown on earth, photographs, and crew transcripts. The only usable data of the crystal distribution along the wire and general appearance is the CDR's flight and debriefing transcripts. The vial was accidentally dropped while it was being unwrapped at MSFC and all the silver crystals were broken off the copper wire. Some individual crystals may be recovered.

7. Anomalies. The only anomaly that occurred during the performance of this demonstration was the loss of the 35mm film. The entire data portion of the TV106 magazine, CI-115 was blank. The sensitometric strips at each end were good and there was no evidence of slippage in the drive slots. The reason for the blank film has not been established. TV coverage might have yielded some useful data based on the excellent results of TV101 and TV107 closeups.

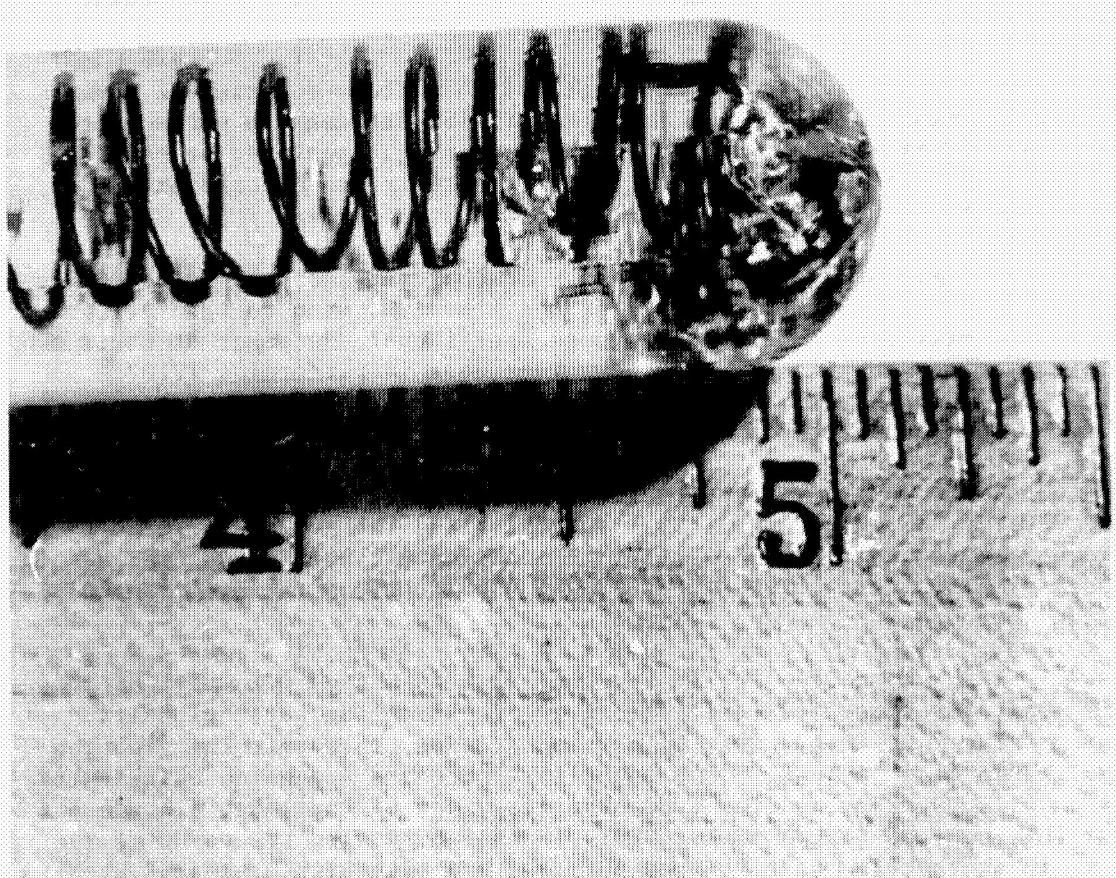


FIGURE VII-6. TV106 SILVER CRYSTALS

G. TV107 - Fluid Mechanics Series

The Investigators for TV107 (SD9) are Brian Dunlop, (Student Investigator for Experiment ED78); Austintown Fitch High School, Youngstown, Ohio; Dr. S. Bourgeois, Huntsville Research and Engineering Center, Lockheed Missiles and Space Company, Huntsville, Alabama; Ms. Barbara Facemire, Space Sciences Laboratory, MSFC, Huntsville, Alabama; Mr. Otha Vaughn, Aero-Astrodynamics Laboratory, MSFC, Huntsville, Alabama; Dr. R. Frost, General Electric, Valley Forge, Pennsylvania; and Dr. Owen Garriott, SL-3 SPT, JSC, Houston, Texas. The blow tube was fabricated and packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description

a. Objectives. The objectives were to determine fluid behavior in zero-g by observing: oscillation damping times; surface wetting characteristics; droplet impact and coalescence; vortex formation and damping; and rotation of free floating fluid globules.

b. Concept. The concept was to perform a series of investigations with free floating fluids and fluids attached to surfaces to meet the objectives (see figure VII-7). Although checklist procedures were provided, the crew was expected to use their own discretion in determining the best methods of handling fluids in zero-g.

c. Hardware Description. The hardware was all on-board Skylab operational equipment except for the blow tube used to spin a free-floating water globule. The crew used operational equipment at their own discretion and the Experimenn ED52 spider cage in performing TV107. Video recordings were made using the TV camera with the closeup lens. An attempt was made to photograph one sequence with the 16mm DAC.

2. Demonstration Operation. Practice was started by the PLT at 1100 GMT on DOY 003. On DOY 005, the PLT asked the ground to identify an alcohol source for surface wetting. Since the alcohol in the IMSS was in short supply, instructions to use a wet wipe to clean the blood smear slide were sent.

The PLT started the TV sequence at 2044 GMT on DOY 005. He made six runs, investigating oscillations in free-floating water globules using "wire bent into a sort of horseshoe shape" to handle the globules and induce oscillations. The checklist procedure suggested quick extraction of two syringe needles from opposite sides of the water globule but the PLT reported at 1654 GMT on DOY 010 that he "tried the point of the wire in the bubble [and] you can pull out and very little happens at all - - all you get is the tiniest little vibration".

The PLT attempted the impact and coalescence demonstration. He maneuvered two globules to collide but they did not combine. He reported, "actually I think they're touching and bouncing apart, which is sort of interesting". The next attempt achieved a higher velocity between the

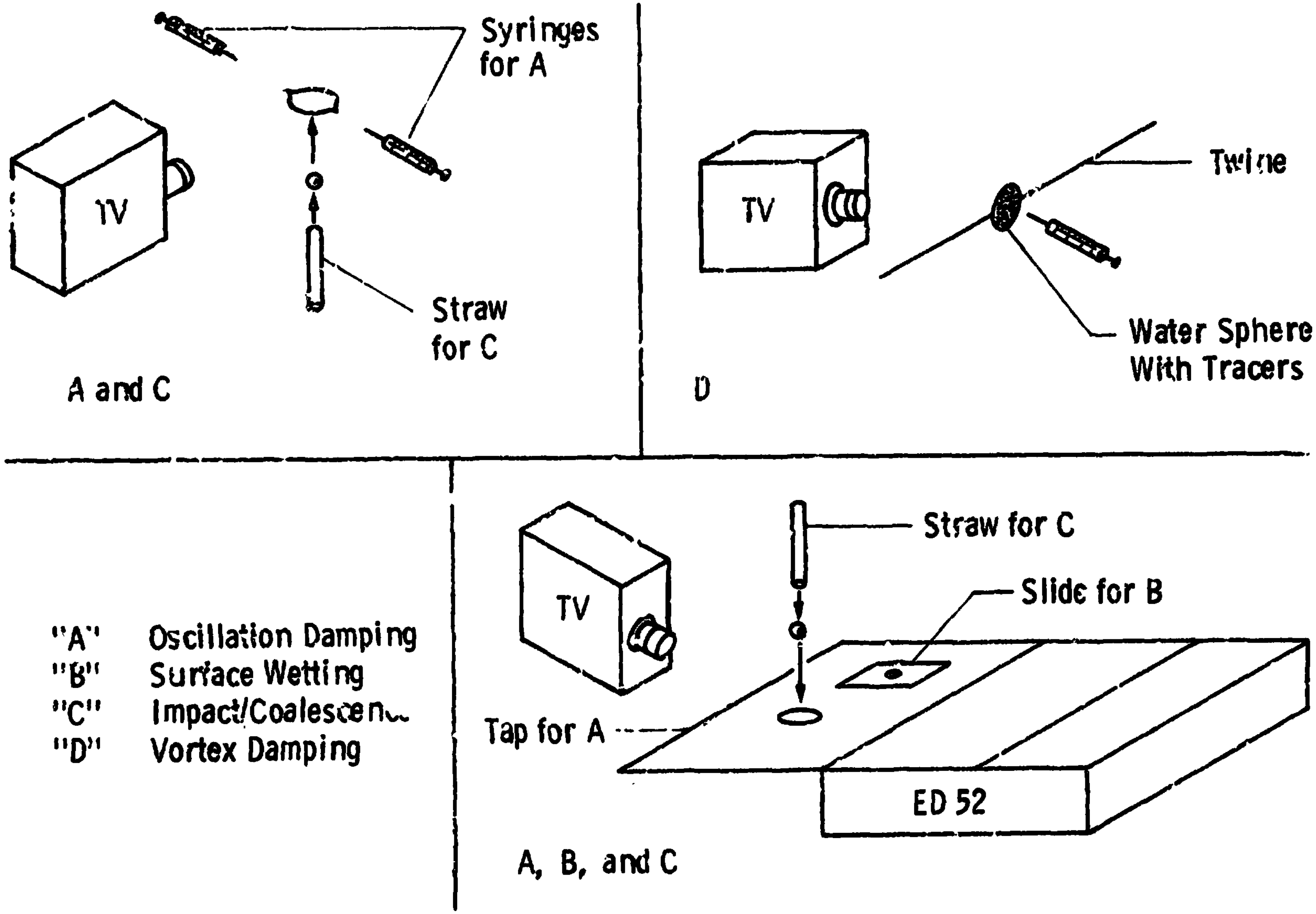


FIGURE VII-7. TV107 FLUID MECHANICS SERIES

globules and they combined into one large globule.

The PLT worked with two large hemispherical water globules attached to a non-wetting surface. He first blew on the globule to induce rotation, which caused it to be asymmetrical. He blew down on the globule and reported that he could "actually blow it into a donut". Short puffs induced oscillations.

The next demonstration was internal vortex formation by injecting water into the globule. Onion chips were added to the globule to make internal flow patterns visible. He demonstrated wetting of water on clear plastic, aluminum and paper surfaces. The water formed a hemispherical globule on the plastic and metal surfaces but on the paper it "made a very low dome".

The PLT described a zero-g drinking cup he invented while practicing for TV107. The cup was formed by inverting the food can jam insert to make an annular water cavity. The cup was filled by squirting water from the hand gun onto the center pedestal (jam insert). It would flow into the cavity and be retained until the center pedestal was covered. Water retention was quite stable, as long as the center pedestal was not covered, permitting both linear acceleration and water rotation (i.e., stirring) by cup movement. He took the first drink from an open cup in zero-g. During the postflight debriefing, the PLT noted a regular empty food can could be overfilled until the water formed a convex surface up to a maximum edge angle of about 20 degrees.

A demonstration recorded on TV without voice comment was the air inflation of a large free floating water globule. The PLT was able to inject three large syringes of air into the bubble before it burst.

At the completion of the TV recording, the PLT noted that "this has been a lot of fun for me and I've gotten a big kick out of it - - I'm proud of my new invention, the zero-g drinking cup -- cheers!" His comment shows the underlying science demonstration program objective of providing a change of pace for the crew was achieved.

During this first sequence, the PLT completed all the checklist objectives except slide surface wetting and free-floating globule rotation with the blow tube. He "did not do the slides because I didn't have the zephiran squeezed out" of a wet wipe. The PLT reported "I couldn't develop the skills to do that [blow tube] at the time". During the postflight debriefing, he said he never could rotate a globule with the blow tube because it was blown away from the tube before it gained any significant rotational velocity.

On DOY 007, the PLT reported that "I was getting ready to photograph TV107 yesterday [and] I had two jams - - one of them was finally diagnosed as a break and the other one I was able to use a little tool and thread it through and get it working again". Although the original plan was to record this demonstration on 16mm color film, TV was

successfully used for all the data sequences. TV permitted monitoring, adjustment of the field-of-view, focusing and lighting, and real time data analysis. The time that the PLT was to devote to TV107 photography on DOY 005 was apparently used fixing the camera.

On DOY 010, CAPCOM relayed the Investigators' video recording review results to the crew and requested that surface wetting with alcohol (zephiran), globule rotation, and additional globule oscillations be attempted. It was requested that oscillations be initiated in a completely still globule, and be observed until completely damped out. CAPCOM informed the PLT that "your fluid demonstration experiment has been picked up on TV around the country and we're getting calls from physicists - - wanting to talk about - - that hemisphere part of the experiment you did, - - it was, in general, terrific".

On DOY 022, the SPT started a second fluid demonstration sequence. He restrained a "50cc sphere of water, lightly colored", on a thread and made seven oscillation runs, the first four were attempts to achieve symmetric (induced from both sides simultaneously) oscillations. The SPT used an original technique. Large syringe pistons were used to squeeze the globule. Their front surface was coated with Krytox grease to make it non-wetting, a technique learned during TV101 performance. The tools were used to squeeze the globule and initiate oscillations by quickly withdrawing them. The recorded TV showed this technique to be effective.

Starting at 2339 GMT on DOY 022, the SPT started a second set of oscillation runs with "big brother - - 100 cc's of fluid, water slightly colored". He made three symmetrical runs and three asymmetric runs. The shapes were described as: a gentle symmetric oscillation "essentially goes to an elliptical shape in one direction and then moves into an elliptical shape 90 degrees from that" and "at extreme oscillation it looks like a square with rounded corners"; "an irregular [asymmetric oscillation formed] a triangle with rounded corners".

The SPT injected air into a water globule and made two oscillation runs. These runs were unsuccessful and the SPT tried again on DOY 023, starting at 2335 GMT. He accomplished two runs and observed that "this sphere did not oscillate anywhere near to the degree that it did before, even though it received the same forces initially; -- it damped very quickly".

At 2355 GMT, the SPT added soap to a water globule making about a one-percent solution. He observed "the reduced surface tension makes it a lot harder to work with". He used the syringe pistons to initiate oscillations and observed that it "oscillates a little bit slower and it seems to damp quicker".

The SPT suspended two globules of about 30 cc each, one dyed with grape and the other with strawberry drink, to investigate impact and coalescence. The globules were impacted (at about 0151 GMT, DOY 24) and coalesced even though, "we had a pretty big impact parameter there,

- - which is the distance between the line of centers".

The third fluid mechanics sequence performed by the PLT started at 1625 GMT on DOY 026. He made a tool of his own design consisting of "two food cans -- between which I've stretched three threads [which] enables me to move the bubble around and maneuver it". His plan was to rotate the globule until it separated and then maneuver the resulting globules into a collision to observe coalescence. He accomplished four rotation runs and three collisions, losing one pair of globules after separation. These runs were successful and produced results unanticipated by the investigators. The anticipated globule rotation results were "they'll probably flatten out, they may even fission like a nucleus, or they may go donut shape on you". What happened consistently in all the practice and data runs, was the globule "assumes more or less a peanut shape or a dog-bone shape - - an hour glass shape, - - and at a more or less critical speed - - you can see more or less two teardrop shapes forming". The PLT was concerned that acceleration was breaking the globule but during the fourth run he achieved an undisturbed separation. He commented "I'd like to get them to separate on their own, and there they go - - it's very difficult to get them to do that - - quite happy I got that recorded on television". Some globules contained air bubbles which moved to the rotation axis due to centrifugal force on the liquid.

The impact runs were successful. During the first collision, the PLT observed "this is very interesting because they did not go together - - they bounced off each other". The second collision resulted in coalescence. Subsequent runs resulted in coalescence on the first impact.

During the postflight debriefing, the PLT and SPT added some general comments and suggestions about performing fluid experiments in zero-g. The PLT recommended that lots of towels be available and the fluids work be performed in an area where no damage can result from spills because the water will be all over, especially during the early practice sessions. He said that a lot of time should be allowed for learning fluid handling. They recommended that non-wetting surfaces be used to handle fluids because the fluid spreads all over a wetting surface, preventing release of free floating globules. They noted that air currents had a significant effect on free floating globules, making it difficult to position them.

3. Constraints. The demonstration constraints were successfully met during the mission.

4. Hardware Performance. The operational equipment performed as expected except the 16mm DAT. It jammed twice and no movies were made. The crew used onboard equipment to assembly a drinking cup, and tools to compress, rotate and maneuver free floating globules.

5. Interfaces. The interfaces performed satisfactorily during the mission. Although numerous "spills" occurred, the crew reported no damage from getting things wet.

6. Return Data. The return data were the video recordings and the crew voice transcripts.

7. Anomalies. No anomalies occurred during the performance of this demonstration other than fluid spills. Spills did not result in any problems.

H. TV108 - Neutron Environment

The Investigators for TV108 (SD34) are Dr. G. J. Fishman, Teledyne Brown Engineering, Huntsville, Alabama; and Dr. T. A. Parnell, Space Sciences Laboratory, MSFC, Huntsville, Alabama. The samples were prepared at MSFC and packaged in a food can at JSC, Houston, Texas.

1. Demonstration Description

a. Objectives. The objective was to measure the neutron energy spectrum and density near massive and non-massive Skylab objects.

b. Concept. The concept was to expose metal samples, susceptible to various energy levels of neutron activation, to the internal Skylab environment near massive objects (the film valut and a water tank) and non-massive objects (the OWS dome and sidewall), and determine neutron flux by postflight analyses. The returned samples were to be analyzed in the MSFC low-level gamma-ray spectroscopy facility. This data and known material cross section data would yield time-integrated measurements of the neutron environment.

c. Hardware Description. Each activation packet was made with five metal samples sewn between two Beta cloth sheets using nylon thread. Four identical activation packets were packaged in a 4 inch diameter by 1-1/4 inch food can for launch.

The samples were hafnium, nickel, titanium, tantalem and cadmium-covered tantalum. The first four samples were 1.9 by 1.9 by 0.32 cm and weighed 10.25, 5.25, 15.25 and 19 gm, respectively. The fifth sample was made with a tantalum core identical to the tantalum sample and wrapped with 0.06 cm thick cadmium sheet (6 gm per sample). The cadmium-covered tantalum sample was encapsulated in RTV-118 (5 gm per sample) to prevent cadmium outgassing.

2. Demonstration Operation. The activation packets were deployed during DOY 324. At 0151 GMT on DOY 325, the CDR reported that "we've just discovered that there is a new thing called the neutron environment - - its some sort of demonstration which none of us has even seen before - - I've got the sinking feeling that those four photos I took last night with the Nikon for ED76 neutron detectors was meant for this one; - - as part of the day 4 transfers, we discovered this demo, and we have deployed it". This was the first mention of packet deployment so a precise deployment time is not available. The only transfers recorded in the as-flown flight plan during DOY 324 were those performed by the CDR between 2130 and 2445 GMT. The packets were taped in the following locations:

SN 001 - In film valut drawer J (drawer bottom)
SN 002 - On water tank number 9 between ED76 detectors
(between A-4 and end of tank)
SN 003 - OWS dome approximately 6 inches from light No. 8
SN 004 - OWS sleep compartment (aft end on outboard wall)

Four photographs recording the activation packets locations and positions were taken during DOY 327 on magazine CI-110. No mention was made of the time the photographs were taken. Figure VII-8 shows a packet deployed in the sleep compartment.

The activation packets were transferred to the CM for return early on DOY 036. The packets were retrieved sometime between 1055 GMT, when the crew was awakened, and 1158 GMT when the CDR reported packets stowage. The packets were deployed approximately 76-1/2 days.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The crew reported no hardware problems.

5. Interfaces. All demonstration interfaces performed satisfactorily during the mission.

6. Return Data. The return data was the four activation packets and four 35mm photographs.

7. Anomalies. No anomalies occurred during the mission

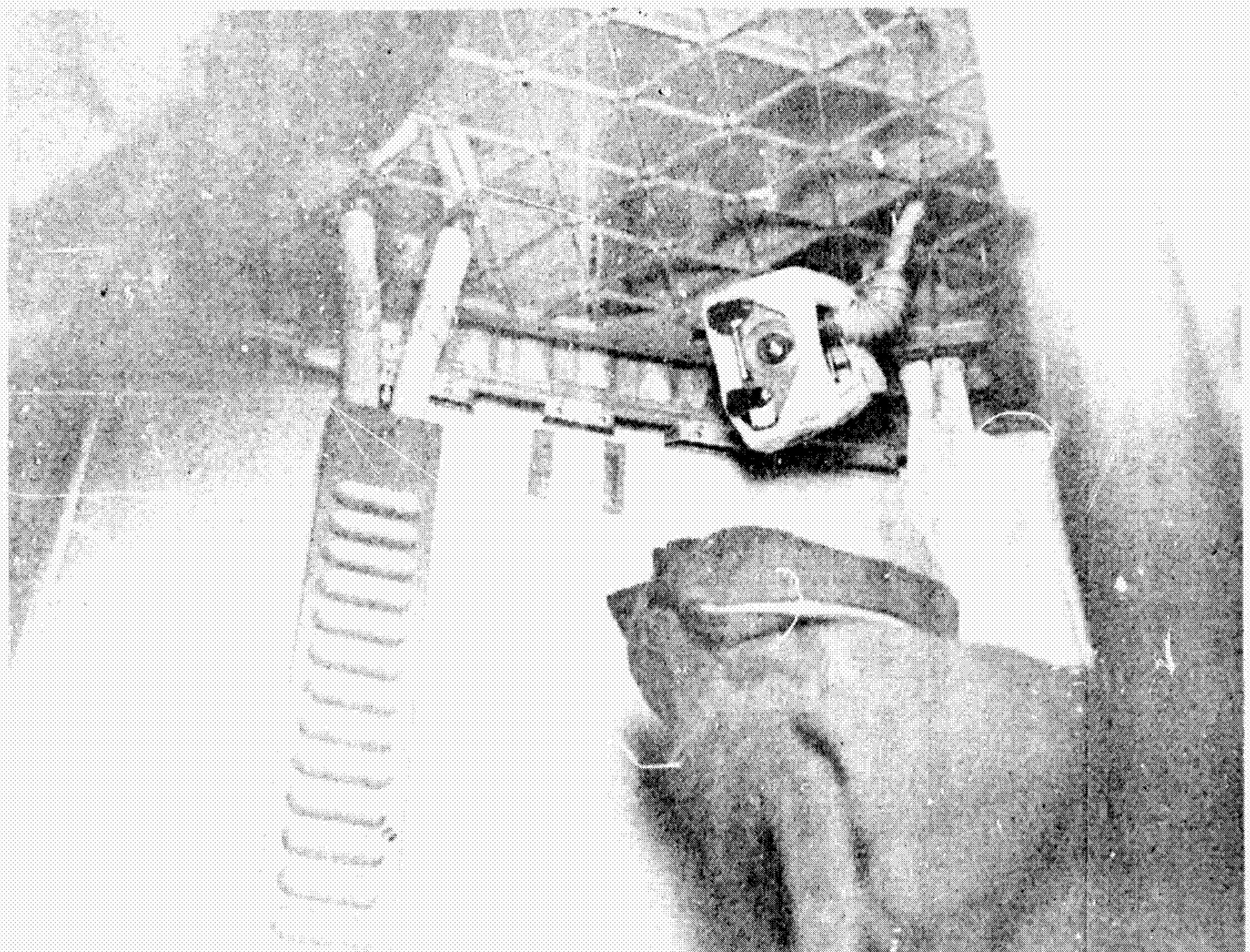


FIGURE VII-8. TV108 NEUTRON ENVIRONMENT PACKET ON WATER TANK

I. TV110 - Orbital Mechanics

The Investigator for TV110 (SD30) is Robert L. Holland, Space Science Laboratory, MSFC, Huntsville, Alabama. A transparent sheet for this demonstration was supplied by MSFC and packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description

a. Objectives. The objective was to demonstrate the independent relative motion between objects in similar orbits.

b. Concept. The concept was to release two spheres in the fields-of-view of two motion picture cameras, facing 90 degrees to each other, to record spacecraft motion relative to the spheres. Plastic sheets were to be used to minimize air movement forces. The spheres were to be of different densities (different ballistic coefficients) to permit normalizing air flow effects during data analysis.

An alternate concept, suggested by the SL-3 SPT, was that spheres be released inside a locker covered with a transparent sheet to eliminate air movement.

The concept implemented by the SL-4 crew was to observe the apparent motion of free floating spheres during a short trim burn.

c. Hardware Description. The spheres to be used were two balls from the recreation kit and two aluminum spheres (1/2-inch and 1-inch diameter) from the SL-3 science demonstration kit. The transparent sheet for the alternate concept was a 13 by 18-inch sheet of 1/4-mil FEP teflon.

The demonstration was recorded with TV.

2. Demonstration Operation. At 1309 GMT on DOY 021, the PLT started TV110. He introduced it by describing the trim burn used to adjust the Skylab orbit to achieve ground tracks that permitted repetitive earth observations. He pointed out that "we've noticed on previous maneuvers that even 400 pounds thrust on a 200,000 pound vehicle causes objects to move around because of the acceleration" The PLT suspended three balls (the two aluminum spheres and the handball) in front of the TV camera and at 1312 GMT the 10-second trim burn was performed. The Skylab and TV camera moved quickly away from the balls while the PLT described the demonstration: "okay, now you see the balls starting to move up - - the balls are floating freely but they appear to move relative to the spacecraft because the spacecraft is moving".

3. Constraints. No constraints were applicable to TV110.

4. Hardware Performance. There were no hardware problems.

5. Interfaces. All demonstration interfaces performed satisfactorily during the mission.

6. Return Data. Return data was the video recording and the accompanying voice recording.

7. Anomalies. No anomalies occurred during the mission.

J. TV111 - Ice Melting

The Primary Investigator for TV111 (SD16 Ice Melting) is Dr. guenther Otto, Physics Department, University of Alabama in Huntsville, Huntsville, Alabama. The co-investigator is Dr. Lewis Lacy, Space Sicence Laboratory, MSFC, Huntsville, Alabama. The demonstration was expanded during SL-3 to investigate surface tension effects. The Investigators for the surface tension portion of TV111 are Ms. Barbara R. Facemire, Space Science Laboratory, MSFC, Huntsville, Alabama, and Dr. Philomena Grodzka, Lockheed Missiles and Space Company, Huntsville Research and Engineering Center, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The primary objective of the ice melting demonstration was to observe the liquid-solid interface temporal progression in melting material. The second objective was to obtain zero-g containerless melting data.

The objective of the surface tension effects demonstration was to observe a change in the shape of a spherical water globule when the surface tension was altered asymmetrically.

b. Concept. The concept was to observe and photograph the melting of an "ice cube". A timer and scale were to be placed in the camera field-of-view for recording and subsequent evaluation of the melting rate, and the changing liquid-solid interface. Surface tension was to be altered asymmetrically by introducing liquid soap on one side of a spherical water globule. Photographs were to be made using the 16mm DAC.

c. Hardware Description. Available Skylab equipment was used. The water was frozen in a Scopedex cylindrical plastic pill dispenser from SL-2 IMSS can 1034. An IMSS microbiology kit dry swab was frozen in the ice to facilitate handling and positioning. Two strips of one inch tape were stretched between the top of stowage locker 505 to the M509 antenna strut base just below the water tanks in the OWS forward compartment. The sticky side was inboard, facing the camera, see Figure VII-9. A piece of Mosites attached to the swab separated the ice-water from the tape. The M074 specimen mass measurement device (SMMD) was used to determine the weight of the ice and container. A small piece of paper was stuck to the ice surface to permit observation of fluid motion as the ice melted. The M487 velometer was used to measure local air velocity. The M487 ambient thermometer and an M487 tape measure were attached to the tape in the camera field-of-view. A 16mm DAC with an 18mm lens was mounted at camera location F2. A portable high intensity photo lamp was mounted at camera location F1.

The 5cc syringe was used to place a liquid shower soap drop or the water globule during the surface tension demonstration.

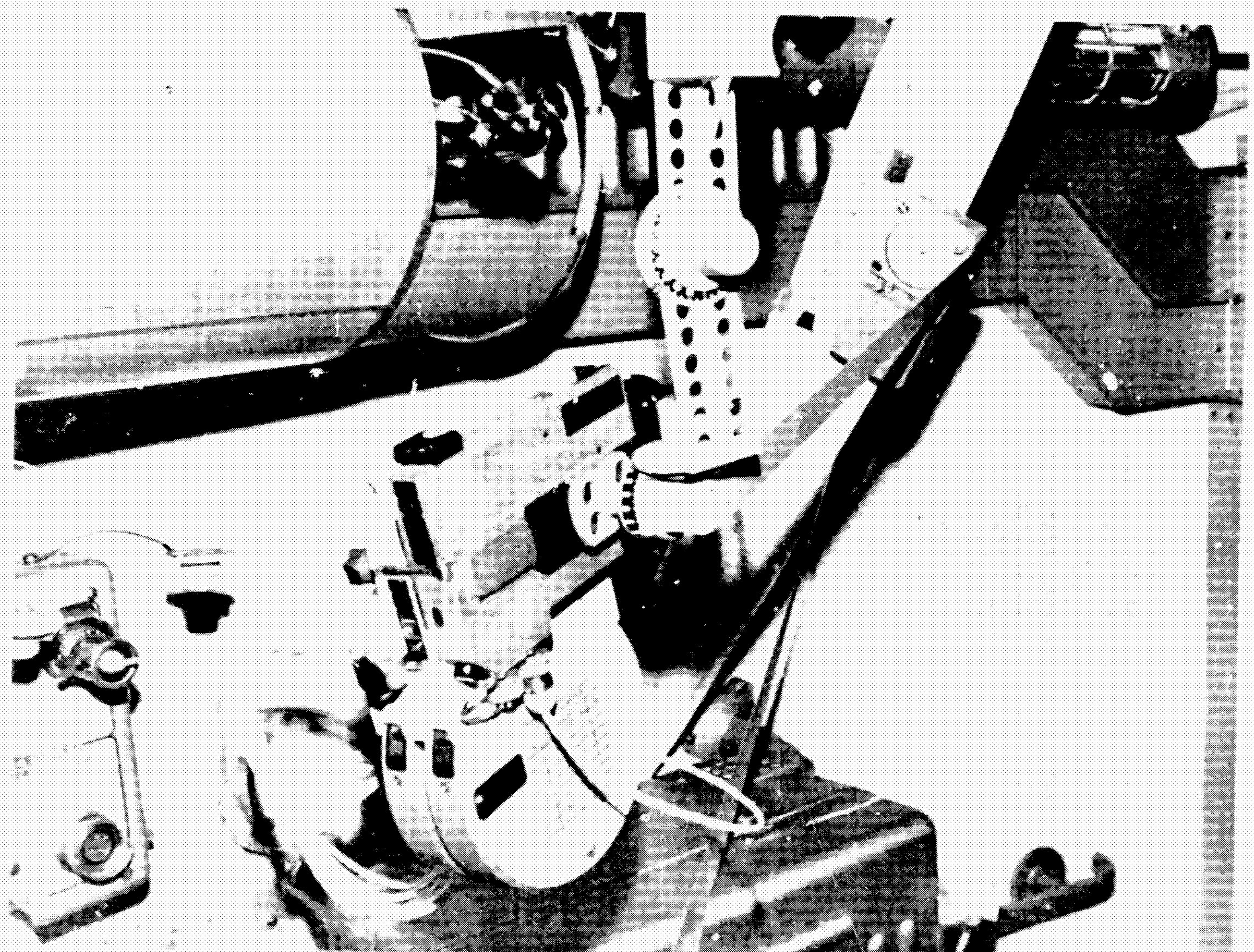


FIG. VII-9. TV111 ICE MELTING AND TV115 DIFFUSION IN LIQUIDS SETUP

2. Demonstration Operation. The pill container was filled with water and placed in the freezer during DOY 263. The PLT reported during the debriefing that he shook the container to remove the air bubbles but couldn't remove them all. It was filled except for a small amount of trapped air.

The ice cylinder was removed from the freezer at approximately 1032 GMT on DOY 264. The PLT observed that the cylinder was bulged in the center but he did not observe any expansion cone at the ends. He did observe that the ice "had made little cracks in itself". The weight of the ice cylinder, swab and container with the containers' snap cap and string removed, was 49.4 ± 0.2 grams (based on the DOY 260 SMMD calibration).

The PLT experienced no difficulty in removing the ice from the container. He held the container in his hand for a few seconds and pushed the ice from the container. It had a frosted appearance, apparently produced by tiny bubbles formed as the dissolved gases came out of solution during freezing. The bubbles had formed in one 90 degree segment of the cylinder. The bubbles location relative to the freezer wall is not known. The ice cylinder was attached to the tape prior to 1[illegible]4[illegible] GMT when the PLT reported that "the thing is up and melting". The elapsed melting time was obtained from the timer in the photographs even though the pictures were out of focus. The PLT measured the air velocity as zero near the demonstration with the M487 velometer. Accounting for instrument accuracy, the air velocity was less than 5 feet/minute.

A few 16mm frames were shot at about five minute intervals throughout the three hours needed to melt the ice cylinder. Initially, melting occurred on all surfaces. Once a film of water formed, it collected on and insulated the cylindrical surface resulting in melting occurring almost entirely on the ends, until sufficient water formed to cover them. The water surface shape was elliptical over the cylindrical section and became spherical as the water covered the cylinder ends. The melting ice cylinder and water globule is shown in figure VII-10.

Less than a 2-inch diameter water globule remained after the ice melting demonstration. The spherical globule shape was slightly distorted by the cotton swab and stick wetting. Small air bubbles distributed throughout the globule resulted from gases dissolved prior to freezing.

The PLT touched the side of the water globule with a liquid shower soap drop to reduce surface tension on one side. The soap spread over the globule surface so rapidly that no shape change could be observed. The water globule attached itself to the needle. As the needle was pulled away, the resultant distortion and oscillations masked any deviations from the spherical shape caused by a surface tension gradient.

A few grape juice drops were added to the globule with the syringe to observe the mixing rate. The globule, wetted the needle when the two touched causing distortion and, large oscillations when contact was broken.

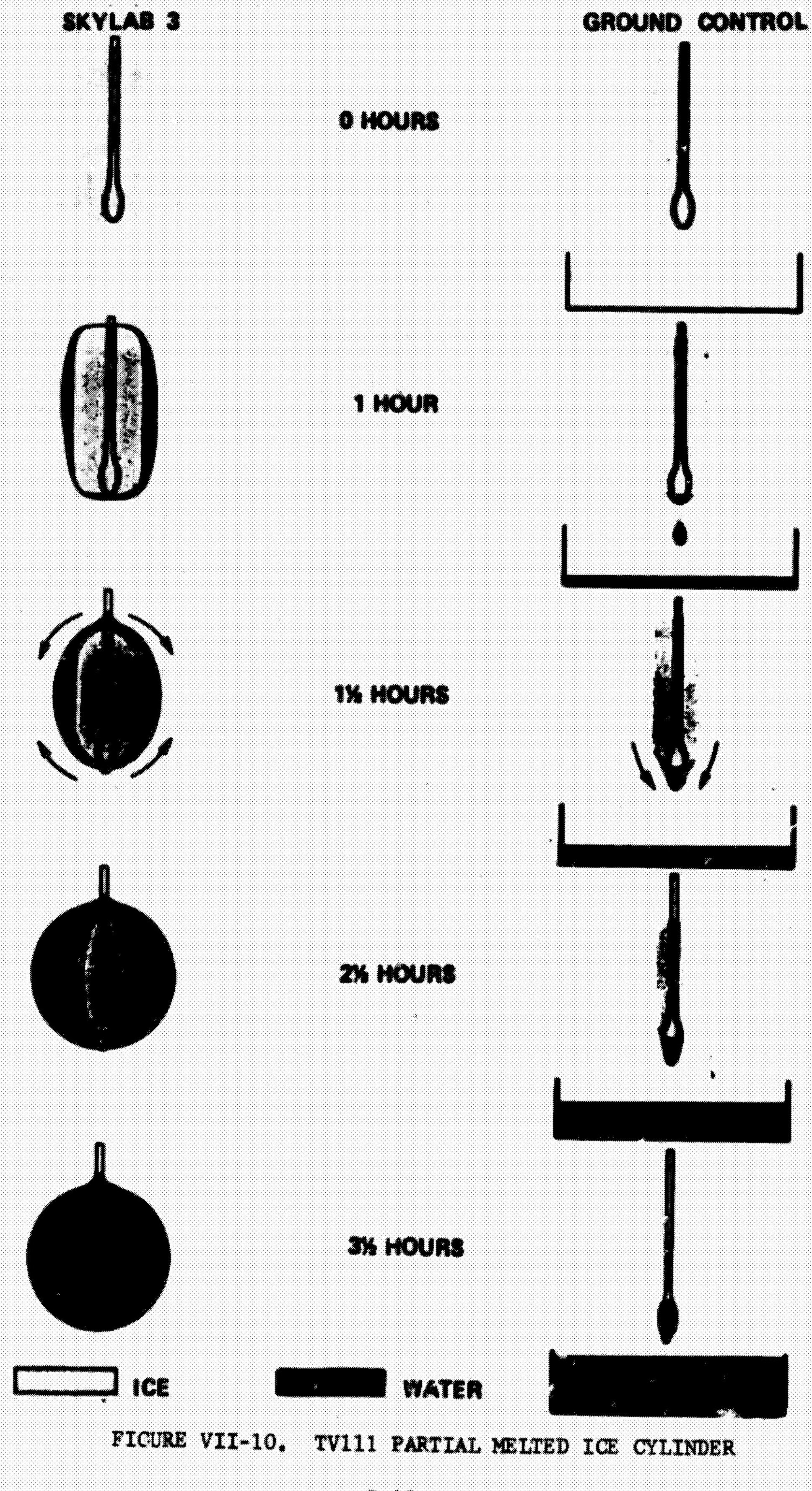


FIGURE VII-10. TV111 PARTIAL MELTED ICE CYLINDER

These damped out in a few seconds. The PLT observed that he had to approach the globule very slowly or the air he pushed produced significant globule movement. Operating and location constraints are essential to air movement control during zero-g fluid experiments.

On his own initiative, the PLT injected air into the globule. His experimence with this globule was different than the SPT's previous experience with pure water globules. The SPT reported that when injecting air into a free floating globule "it will form either one or two large bubbles in the center" and "you can blow it up into a balloon as large as you like, until it explodes". As the PLT injected air into this globule, relatively small uniform bubbles were formed. As more air was injected, more bubbles formed until a limit was reached, producing the appearance of a plastic bag filled with ping pong balls. As more air was injected, individual small bubbles broke through the globule surface. "spitting little bits of the liquid into space". The PLT withdrew fluid and air back into the syringe and ejected a stream against the globule to observe the impact characteristics and the resulting oscillations.

The ice melting demonstration was to be repeated during SL-4 to obtain focused photographs but was not performed due to insufficient crew time.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. All hardware performed as expected.

5. Interfaces. All demonstration interfaces performed satisfactorily during the mission.

6. Return Data. The return data was the 16mm film, voice transcripts and the postflight crew debriefing transcripts.

7. Anomalies. The only anomaly that occurred was the procedural error in determining the distance between the camera and the ice cylinder. The distance should have been measured to the camera's focal plane but was actually measured to the camera's lens. The SL-4 procedures were clarified. Since the ice cylinder was mounted on a piece of Mosites, it was in front of the forceps tube used for diffusion and was nearly in focus.

K. TV112 - Ice Formation

NOTE: Demonstration TV112 was not performed during the Skylab program due to insufficient crew time. The following provides some TV112 information.

The Investigator for TV112 (SD17) is Ms. Barbara R. Facemire, Space Sciences Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The objectives were to observe: the freezing characteristics of water and aqueous-solution globules in zero-g (specifically, bubble distribution resulting from dissolved gases coming out of solution, segregation of solute, effects of expansions, and time of freezing), and a water drop freezing on an ice sphere.

b. Concept. The concept was to suspend two globules on a piece of twine taped across a corner of a food freezer, and observe and photograph them periodically during freezing. One globule was to be pure water, and the other dyed with an onboard solute. A small drop of water was to be placed on one frozen globule and observed and photographed periodically.

c. Hardware Description. The hardware was to be available Skylab equipment. Selection of twine, syringe and solute was at crew option. The 35mm Nikon camera and the portable high intensity photo lamp were to be used for photography.

2. Demonstration Operation. TV112 procedures were available during SL-4 but it was not performed because of insufficient crew time.

L. TV113 - Effervescence

NOTE: Demonstration TV113 was not performed during the Skylab program due to insufficient crew time. The following provides some TV113 information.

The Investigator for TV113 (SD18) is Dr. A. R. Hibbs, Jet Propulsion Laboratory, Pasadena, California. The seltzer tablets were packaged in the SL-4 science demonstration kit at JSC, Houston, Texas.

1. Demonstration Description

a. Objectives. The objectives were to observe bubble formation of an effervescent reaction in zero-g and to determine whether or not the reaction was self-quenching as the resultant gas bubble grew.

b. Concept. The concept was to fill a transparent container with water, insert a seltzer tablet, and observe the reaction.

c. Hardware Description. The transparent container selection was left to the crew. Two Alka-Seltzer tablets were packaged in the SL-4 science demonstration kit. The reaction was to be recorded with TV.

2. Demonstration Operation. TV113 procedures were available during SL-4 but it was not performed because of insufficient crew time.

M. TV114 - Acoustic Positioning

NOTE: Demonstration TV114 was not performed during the Skylab program due to insufficient crew time. The following provides some TV114 information.

The Primary Investigator for TV114 (SD24) is Dr. Taylor Wang, Jet Propulsion Laboratory, Pasadena, California. The Co-Investigator is Mr. Otha Vaughan, Aero-Astrodynamics Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The objective was to demonstrate the feasibility of using the pressure gradient of acoustical standing waves to position and control the motion of small particles (liquid and solid) in a weightless environment.

b. Concept. The concept was to produce acoustical standing waves by a combination of radiated and reflected sound. Discrete frequencies played on a tape recorder were to provide the radiated sound and a hemispherical reflector, the reflected sound. The reflector was to be manually positioned to produce the standing wave. A few water droplets were to be released between the tape recorder and the reflector. They were expected to move to an anti-modal low pressure point where they were expected to coalesce into a large constrained globule.

c. Hardware Description. Two tones were recorded on the SL-4 SPT's entertainment tape number 7, side 2. The tones were 2,000 and 3,000 hertz and each lasted five minutes. A Sony TC124 recorder was available for playing. The recorder was to be taped to the wardroom table on tope of two full food cans. The crew seat was to be rotated up and taped to the back of the recorder for support. The 3/4-inch gray tape was to be used for recorder and reflector assemblies.

The reflector was to be assembled by taping a large, hemispherical blister patch from the repair kit (lockers E620 or M144) to the back of the E041 maze (eye-hand coordination test fixture), using an empty food can as a spacer. Based on ground tests, the standing wave was expected to occur with the reflector about four to six inches from the tape recorder. A syringe was to be used to release the water drops. The M487 tape measure was to be placed in the camera field-of-view to permit postflight setup scaling, drop sizing and position determination. TV was to be used for recording.

2. Demonstration Operation.
TV114 procedures were available during SL-4 but it was not performed because of insufficient crew time.

N. TV115 - Diffusion in Liquids

The primary Investigator for TV115 (SD15) is Ms. Barbara R. Facemire, Space Sciences Laboratory, MSFC, Huntsville, Alabama. The co-investigator is Mr. Tommy C. Bannister, also of the Space Sciences Laboratory.

1. Demonstration Description

a. Objectives. The objectives were to obtain data on zero-g mass diffusion by photographically recording the diffusion rate of a dark liquid into water, to demonstrate the rate of molecular diffusion without convective mixing.

b. Concept. A dark liquid, such as tea, was to be brought in contact with water in a transparent container without introducing fluid motions. The interface between the fluids was to be observed. The interface timer and a scale were to be photographed periodically to permit postflight diffusion rate evaluation.

c. Hardware Description. The TV111 setup, shown in figure VII-9 was to be used and utilized available Skylab equipment.

A transparent plastic forceps container was used to hold the liquids (by the end of SL-3, it was no longer necessary to preserve the sterility of one forceps contained in the IMSS). The container was approximately 1/2-inch diameter by 6-inches long, and had a threaded sealing cap with a synthetic fiber wad to absorb moisture. A second fiber wad was used after the initial demonstration was unsuccessful.

A plastic accordion-type drink mixer/dispenser, powdered tea, and a 5cc syringe comprised the remaining equipment. The syringe was used to transfer a concentrated tea solution from the tea container to the forceps container.

2. Demonstration Operation. The diffusion demonstration was tried four times during DOY 263 by the PLT. The first try, at 1236 GMT, resulted in no contact between the tea and the water. The tea stayed on the fiber wad without diffusing into it. During the second try, at 1324 GMT, the PLT withdrew the tea into the syringe and reinjected it directly into the wad. Some tea was squirted past the wad down into the water. Because of this, the PLT initiated the demonstration a third time at 1545 GMT. He saturated the fiber wad with tea and pushed it, allowing the trapped air to escape, until it contacted the water. The tea to water interface at this time was in the wad and was not flat. The PLT described it as "mottled". The difficulty in establishing the interface in the fiber wad caused the PLT to suggest that the fiber wad be removed and that he just lay the tea on the water. He commented that "if it doesn't work by tonight, we'll think of a different way".

The tea used in the first three attempts was frothy, with small air bubbles distributed through the tea when it was injected into the forceps container. The concentrated tea was described by the PLT as "syrupy". It was presweetened and contained lemon flavoring, and was mixed with one ounce of water instead of the normal 7-1/2 ounces. The PLT felt that the solution might have been too thick to diffuse through the fiber wad.

At 1725 GMT on DOY 263, the CAPCOM asked the PLT to reinitiate the demonstration using the original procedure, and stated that the expected diffusion rate was approximately one inch in 36 hours. The PLT had expected diffusion to occur more rapidly.

For the fourth try, at 1823 GMT, the PLT placed about 4 inches of water in the container followed by a fresh water saturated wad about 1/2-inch thick. He centrifuged the tea in the drink mixer/dispenser to eliminate bubbles, and injected about 7/8-inch of tea into the container. The tea and water formed a good, bubble-free interface at the tea side of the wad.

The PLT reported the next day on at least three occassions that no diffusion had occurred. The last report was at 1338 GMT. At 1544 GMT, CAPCOM requested the crew "to reinitialize that experiment using your own ingenuity" and "let it diffuse on past the EVA and see if we can get some data".

The results of the fifth and final setup were reported during the postflight debriefing. The PLT deleted the fiber wad and placed the tea on top of the water. There was an air bubble between the tea and the water that the PLT removed with the syringe, producing a smooth, continuous interface. Although there was no voice-recorded description, the final setup was initiated some time late in DOY 264 and allowed to diffuse for about three days. Elapsed time is available for diffusion rate evaluation from the 16mm photographs that were taken a frames at a time. The DAC was not focused on the forceps container due to a procedural error. It was difficult, but possible, to read the timer.

Diffusion did occur in the final setup. The diffusion front assumed an unexpected bullet shape, with little or no diffusion occurring at the plastic tube wall. Based on preliminary information, the visible diffusion front advanced 1.96 cm along the tube centerline during the 51-1/2 hours of the demonstration.

TV115 was to be repeated during SL-4 to obtain in-focus photographs and to test the hypothesis that electrostatic repulsion between the tea particles and the plastic wall impeded diffusion along the wall. SL-4 operation was not achieved because of insufficient crew time.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. All the operational equipment used performed as expected. The syringe was used without the needle to reduce the ejection velocity and provide better control in handling the tea. During the second setup using the syringe with needle, tea was inadvertently squirted into the water. In the final setup with the needle removed, the PLT was able to place the tea on the water surface w thout disturbing it.

5. Interfaces. The demonstration interfaces performed satisfactorily during the mission.

6. Return Data. The return data was 16mm film. Voice transcripts provided background information and a description of the setup problems.

7. Anomalies. The only anomaly that occurred during this demonstration was a procedural error in determining the distance between the camera and the container. The distance should have been measured to the camera's focal plane but was actually measured to the camera's lens. The SL-4 procedures were clarified.

O. TV116 - Lens Formation

NOTE: Demonstration TV116 was not performed during the Skylab program due to insufficient crew time. The following provides some TV116 information.

The Investigators for TV116 (SD23) are Dr. W. A. Oran, and Dr. R. Kroes, Space Science Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The objectives were to demonstrate formation of lenses shaped by liquid surface tension in zero-g and to obtain preliminary data on the optical properties of such lenses.

b. Concept. The primary concept was to take edge-view photographs to record the maximum and minimum sized water-lenses formed on a wire loop and to determine the focal lengths and optical properties by taking photographs through the lenses. Various loop sizes and pure water and soap solutions were to be used.

Time permitting, the concept was to be extended to observe characteristics of a water prism defined by a bent-wire shape, and to form a molten soap lens to be returned after solidification for postflight evaluation.

c. Hardware Description. TV116 was to use available onboard Skylab hardware. Tool kit safety wire (locker E623) was to be used to form the loops and prism. An M133 electrolyte dispenser was to be used to handle the liquids.

A one cubic inch piece of bar soap was to be melted in the food tray. A one inch diameter wire loop was to be dipped into the molten soap to form a lens about 1/2-inch thick. The lnes was to be wrapped for return after solidification.

2. Demonstration Operation. TV116 procedures were available during SL-4 but it was not performed because of insufficient crew time.

P. TV117 - Charged Particle Mobility

The Primary Investigator for TV117 (SD35) is Dr. Milan Bier, Veterans Administration Hospital, Tucson, Arizona. Co-Investigators are Dr. R. S. Snyder and S. B. Wall, Astronautics Laboratory, MSFC, Huntsville, Alabama. The samples were prepared by Dr. Bier and the charged particle mobility device was assembled by the Astronautics Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The objective was to observe and photograph separation of sedimenting and non-sedimenting particles in suspension in an electric field in a zero-g environment.

b. Concept. The concept was to apply a 28-volt potential across each of two fluid columns, one fluid being red blood cells and the second protein; and to observe particle migration in the tubes and the change in direction caused by polarity reversal.

c. Hardware Description. The samples were contained in a charged particle mobility device (CPMD) consisting of two cells. Each cell consisted of a sample tube with reservoirs and electrodes at each end, and a manually operated gate valve between the sample reservoirs and buffer solutions. An electrical connector provided 28-volt spacecraft power from a DAC power cable. Switches controlled power and reversed each cell polarity. The buffer solutions provided a uniform diffusion front during operation. A CPMD photograph is in figure VII-11.

The CPMD was launched in the Experiment ED31 food overcan. The OWS chiller was to be used during stowage. The CPMD was returned in the IMSS resupply kit.

The CPMD was mounted in the Experiment ED52 spider cage. The 35mm Nikon camera was mounted on the ED52 bracket to fix the distance and prevent movement. Two high intensity lights were mounted on each side of the cage for photographic illumination.

2. Demonstration Operation. A revised procedure was transmitted to the crew via the teleprinter on DOY 332. It listed the equipment required in the first step, changed the performance location to the MDA and gave specific photographic set up instructions and camera settings. The MDA operational location was selected to enable the crew to perform TV117 during ATM operations.

At 2326 GMT on DOY 334, the SPT reported that the CPMD "is not in the food chiller". CAPCOM informed him that if not in the chiller, the CPMD must not have been transferred and would still be in CM locker A-4.

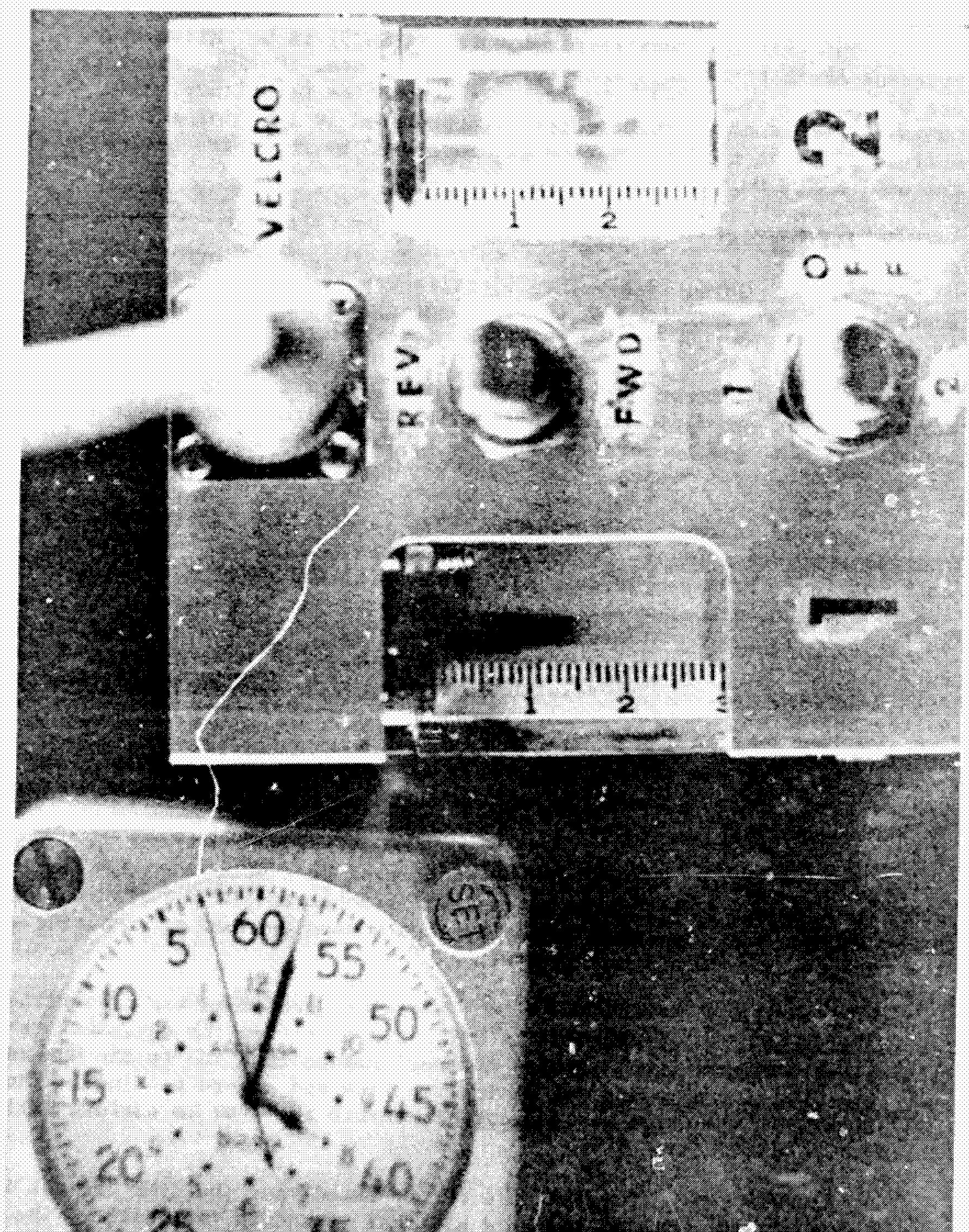


FIGURE VII-11. TV117 CHARGED PARTICLE MOBILITY DEVICE

At 0059 GMT on DOY 335, the SPT reported "I found it - - it was in A-8". He remarked on DOY 341, 0409 GMT that although the PLT's activation procedure was supposed to take care of the transfer of the CPMD, "the PLT was not feeling too steamy the first couple of days and somehow that item got overlooked - - and for that we're sorry". As a result, the red blood cell and protein samples were exposed to room temperatures for nearly two weeks longer than planned. They were to have been chilled between activation and performance. The high storage temperature possibly degraded the red blood cells and broke down the proteins.

The SPT reported during DOY 335 (0059 GMT) that "I've got the experiment being set up now". At 0348 GMT, he reported that he had stowed the CPMD but the rest of the equipment was left partially set up in the MDA.

On DOY 339, seven minutes were scheduled for TV117 preparation. At 0051 GMT, the SPT reported that "we never got that thing put together - - it was in the MDA, [off the EREP foot platform and] I had to move it down to the OWS, the parts are over there in the corner with lots of gray tape wrapped around them - - it's going to take a little more time and gray tape to get it all put together". He noted on DOY 390 at 1304 GMT, that "it takes a fair amount of doing to get all that stuff put together, especially the first time, and I've never seen the gear [and] the procedures". He observed later that it took the "better part of a roll of gray tape" for demonstration set up.

At 2339 GMT on DOY 340, the SPT reported that "I got the fellow all set up and ran the first one" and that "I'm just finishing up running the ops 2 on side number 2", and that the first run was made with bubbles should have been removed, but they cannot be removed by tapping, as suggested - - it takes a very skillful shake". Since he missed that part of the procedure, he recommended that he "go back and run [ops 1] again".

The SPT gave a detailed description of the runs in a dump tape, starting at 0408 GMT on DOY 341. During the first run, he observed "a slow drift of the bubbles" at the times he took the second and third photographs. After reversing the voltage, he observed that "the interface was fairly flat and some of the bubbles were imbedded in the red material". The gate on cell one was closed at the end of the first run and the bubbles removed from the tubes of both cells.

After initiating the second run in cell two, the protein sample, the SPT reported "at 2258 [GMT] I saw nothing -- all the way through I saw a big nothing - - I did not notice any differences in color - - for me I was just proving the interface between two similar substances doesn't show up no matter houw you moved it around - - but, I carried out the photo program as called for".

In preparation for run 3, the second operation of cell 1 (red blood cells), the SPT observed that "in the process of trying to get rid of bubbles I had agitated it enough to spread the small amount of red which was trapped in the cylindrical section, I had essentially diffused the rest - - so that the fluid barely showed a trace of it - - uniform color, very slight pink". During this second run with cell 1, the SPT observed that "the interface was very clearly defined but the center had moved out a little bit - - it reminded me very much of the cross section that they show for flow through a pipe - - just a slightly elliptical or bowed interface to it, with the center part extending farther down the tube". He noted specifically, at the time of the third photograph, that "the interface - - had moved away from the walls quite a bit - - all the way up to, I don't know, 1.2 or 1.3 [cm] or so where it finally got back to the walls and the center portion had [migrated] all the way down to 1.74 cm".

After reversing the voltage, "the interface became not as well defined and not as sharp - - it was still down the tube in the center, but now it had become very jagged, and the transition was fairly gradual - - very diffused interface - - the color transition was very gradual". As reverse migration progressed, "there were streamers of diffused red material streaming down - - into the relatively clear fluid which had only a very trace amount of red in it".

At the end of the reverse migration, the SPT reported, "then the interesting thing happened, which kind of surprised me - - the surprising part was [the interface] started to move back down the tube". The migration distance reached a minimum of 0.3 cm when he took the eighth photograph, and reversed again without polarity change when he took the ninth and tenth photographs. The three runs are summarized in Table VII-3, including the times the SPT reported taking photographs and some of his observation.

The demonstration was completed on DOY 341 at 0355 GMT. In conclusion, the SPT said: "It was a fun experiment to do. I wish I had a little more training on it to begin with, so I understood what it was all about, and I would have gone about it in a much more efficient and correct manner. But thanks for the opportunity of doing it. I hope you get something from it".

3. <u>Constraints</u>. The CPMD was to be transferred from the ED31 food overcan to the food chiller during activation and remain there until performance. As descrived in sub-section 2, the CPMD was not chilled resulting in a high probability that the blood had been hemolyzed and the protein had broken down. It was hoped that the samples would remain viable for up to one week with refrigeration. The demonstration was performed after three weeks without refrigeration.

Table VII-3

TV117 CHARGED PARTICLE MOBILITY-RUN SUMMARY (BASED ON CREW TRANSCRIPTS)

Run	Cell	Direction	DOY/GMT	Migration Distance(cm)	Remarks
1	1	Forward	340/2115 15	0	Start
			2115 30		1st photograph
			2121		2nd photo, slow bubble drift
			2130		3rd photo, slow bubble drift
			2136	1.5	4th photo
		Reverse	340/2137		Reversed, 5th photograph
			2145	1.3	6th photo, flat interface
			2147	0.8	7th photo
			2154	0.5	8th photo
			2200	0.5	9th photo
					Cell 1 gate closed, CPMD shaken to move bubbles out of tubes
2	2		340/2253 15	Interface could not be seen.	Start, 1st photo
			2258		2nd photo
			2309		3rd photo
			2314		4th photo
		Reverse	340/2319		Reversed, 5th photo
			2323		6th photo
			2330		7th photo
			2340		8th photo
3	1	Forward	341/0200		Start
			0215	0.8	2nd photo, "center of interface moved out a little bit"
			0226	1.7 to tip of interface	3rd photo, migration at wall 1.2 to 1.3 cm
			0233	2.3 to tip	4th photo
		Reversed	341/0243 30	3.0 to tip	5th photo
			0254	2.0	6th photo, interface now very jagged, very diffused
			0303	1.5 to 1.4	7th photo
			0317	0.3	8th photo
			0336	0.5	9th photo, interface very diffuse & inclined, left side further down tube; migration had reversed, interface moved back down
			0355	0.5+	10th photo,"left side 2 to 3 cm further down [than] right", demonstration terminated.

4. Hardware Performance. The CPMD performed as expected except that the protein cell leaked as discussed in paragraph 7. Mounting the Nikon camera in a predetermined location produced the best closeup 35mm photographs of the science demonstrations.

5. Interface. The only interface difficulty encountered was with the MDA location specified in the procedure. It specified mounting on MDA locker M157 but the SPT reported that it was "all covered up with ATM gear and there was just no place to move that". He mounted the assembly on the EREP foot platform but "it was in the way of all the EREP operations" so he finally moved it to the OWS.

6. Return Data. The return data was the 35mm photographs and crew comments. The CPMD was returned, primarily for evaluation of the hardware, but may also contribute to scientific data analysis.

7. Anomalies. The anomaly that impacted TV117 was the constraint violation discussed in paragraph 4.

The flight hardware was disassembled by the primary investigator and evidence of protein leakage through the sample gate valve was found. The amount of protein left in the gate was extremely small (less than 0.1 mil). The cause of the leakage has not been determined.

Q. TV118 - Cloud Formation

The Investigator for TV118 (SD29) is Mr. Otha Vaughn, Aero-Astrodynamics Laboratory, MSFC, Huntsville, Alabama.

1. Demonstration Description

a. Objectives. The objective was to investigate the lifetime history and dynamics of an expansion cloud in zero-g.

b. Concept. The concept was to compress cabin atmosphere in a closed transparent chamber and, after allowing the gas to reach thermal equilibrium (a few seconds), expand the gas and observe the formation, motion, coalescence and lifetime of the water droplets (cloud).

c. Hardware Description. The M113 electrolyte dispenser was used as a cloud chamber. It is shown in figure VII-12. The dispenser was to be mounted in the portable vise which was to be mounted at a convenient location in the grid floor. The resultant cloud was to be photographed using the 16mm DAC mounted on a universal mount located seven grids from the dispenser. The portable high intensity photo lamp was to be used to backlight the cloud chamber to make the resultant cloud visible. At crew option, the demonstration could have been recorded with the TV system.

2. Demonstration Operation. On DOY 001, a science demonstration opportunity arose - one hour was available but with the stipulation that no follow-up activity be required because it could not be scheduled in the established timeline. MSFC recommended TV118 be performed with step 3 of the procedure (vacuum drying of the M113 electrolyte dispenser) deleted. Unfortunately, all the dispensers used during SL-4 had been disposed of and the one that the SL-3 SPT had stowed for demonstration use had also been discarded. The CDR suggested emptying the dispenser that was currently in use, but that idea was rejected. TV118 was scrubbed for that day and the crew was requested to save the next empty M133 electrolyte dispenser.

On DOY 019 a revised procedure was sent via teleprinter message providing specific DAC settings, and instructing the crew to restrain the M133 electrolyte dispenser in the vise at 20-1/4 inches from the DAC focal plane and to install the high intensity light 7-1/2 inches from the dispenser at 150 degrees from the DAC line of sight. The revised procedure resulted from ground testing which had demonstrated the need for precisely controlled backlighting of the cloud to make it visible.

No further opportunities arose to schedule TV118. On DOY 022, TV118 was added to the shopping list, but it was the last item, and during the balance of the mission there was no further discussion of it.

FIGURE VII-12. TV118 CLOUD FORMATION

During the postflight crew debriefing the CDR and the PLT, said they had tried to make a cloud form about 50 times but the results were negative. Droplets formed on the chamber walls but they never saw a cloud form in the gas. The PLT reported that he tried supersaturation of the gas in the dispenser and a wide range of compression hold times, but nothing worked for him.

3. Constraints. No constraints were requested for this demonstration.

4. Hardware Performance. The only hardware used apparently was the M133 electrolyte dispenser and there were no reported problems in using it.

5. Interfaces. No interfaces were apparently involved in the practice sessions for this demonstration. The crew did not comment on what lighting was used during practice.

6. Return Data. Return data was to be 16mm photographs plus crew comments. However, no data was obtained.

7. Anomalies. The only anomaly encountered was the inability of the crew to form or to see a cloud in the chamber. A cloud may not have formed because there may have been too few particles in the cabin atmosphere to serve as nuclei for droplets. Cloud formation requires a minimum of about 1,000 particles/cc of 0.01μ to 1μ size (0.01μ to 0.1μ particles are best). However, Skylab's atmosphere was extremely clean. Although measurements in the small particle size regime are not available, T003 recorded about 3,000 particles/ft^3 (0.10 particles/cc) of 1μ to 3μ size, indicating that there apparently were far too few particles to form a cloud. The T003 particle analysis indicated the majority to be skin flakes which are non-hygroscopic and make poor droplet nuclei.

Another possible explanation for the crew not seeing a cloud is that the proper backlighting may not have been achieved in the practice runs. The Investigator demonstrated cloud formation on numerous occassions and obtained good ground test photographs. However, the time available between SL-3 and SL-4 did not permit a training session in which the crew could have practiced with the M133 electrolyte dispenser and in which proper backlighting could have been demonstrated.

SECTION VIII. CONCLUSIONS AND RECOMMENDATIONS

The most significant hardware-related conclusions and recommendations drawn from the corollary experiments inflight operations are presented in the following paragraphs. General conclusions relating to the experiment development and integration program are presented in the MSFC Skylab Corollary Experiments Final Technical Report, TM X-64809.

A. Design Philosophy and Guidelines

Skylab corollary experiment operational experience demonstrated the need for additional hardware design guidelines in several areas.

1. Troubleshooting and Inflight Maintenance

Conclusion - Skylab has demonstrated the ability of astronauts to perform inflight maintenance. Several experiment repairs were made during the Skylab missions (e.g., S009 motor replacement, S183 connector jumpering, etc.), although specific ground rules established early in the program prohibited designing hardware for inflight maintenance. Dr. Owen Garriott, SL-3 Science Pilot, stated at the SL-3 debriefing: "I think you can do any job up there that you can do here if you have the right tools and a place to hold everything down and contain all the extra parts." Experiment troubleshooting was made difficult by lack of telemetry or crew displays that directly indicated the desired function. For example, S183 film plate extraction was being indicated, but the plates were not being transferred by the mechanism. The telemetry should have directly detected film plate presence in the focal plane rather than the transfer mechanism movement.

Recommendations - Design manned space flight hardware to facilitate inflight maintenance;

Provide work stations and restraint aids for the performance of maintenance tasks on future manned space vehicles;

Provide telemetry channels or crew status indicators which give direct readout of the specific parameters desired to aid in troubleshooting hardware malfunctions and verifying proper operations; and

Provide viewing capability for inflight observation of external experiments.

2. Experiment Facilities

Conclusion - The M512 Materials Processing Facility was effectively used as a support facility for experiments M479, M551, M5[illegible] M553 and the M518 series. Although not originally planned as a facility it was readily adapted to support these experiments. The M518 Multipurpose Electric Furnace was designed from the outset to be a facility for a series of materials processing experiments which it supported with excellent results.

The S019 AMS was designed to support only S019 but S183 support was added and during the mission it was used, with an adapter launched on SL-4, for S063 and T025. The AMS was successfully used as a facility but would have been more flexible if the inboard interface had been the same as the SAL.

The T027 Photometer System was originally designed as a single experiment, within SAL interface constraints, and then modified to support S073, S149, and the Portable Color Television System, and was considered for support of other proposed experiments. As a result, the T027 hardware changed several times when new requirements were imposed. Redundancy could have been built into the T027 pointing system to directly power the motors without use of logic and relays, thus providing manual pointing capability. This redundancy was incorporated into the unit prepared for possible launch on an SL-3 rescue vehicle at minimal cost. Had this redundancy been in the flight unit it would not have been necessary to eject the photometer and extension mechanism.

Recommendation - Hardware to be used as a facility for multiple experiments should be so designated. The design should incorporate maximum reliability and operational flexibility, and users should adhere to its interface provisions.

3. SAL Experiment Contamination Protection

Conclusion - Experiments extended through the anti-solar SAL cool in a short time below the spacecraft atmospheric dew point. If these experiments are repressurized with spacecraft atmosphere or demounted shortly after retraction, condensation forms on the cool surfaces. To preclude condensation on critical surfaces (e.g., the S019 Articulated Mirror) a desiccant system was provided to dry the repressurizing gas and procedures were invoked requiring that, if the experiment was demounted within a specified time after retraction, the end caps be immediately placed on the canister. This involved either an inordinate delay in demounting the experiment from the SAL or required two crewmen for the normally one-man demount task. The T027 Sample Array System sealed as it was retracted protecting the collector surfaces from exposure to condensation and leaving them in vacuum to preclude oxidation or other contamination of the surfaces.

Recommendation - Provide remote sealing capability in airlock experiments that are contamination sensitive to preclude exposure to spacecraft atmosphere during mounting and demounting and, if required, maintain space vacuum in the experiment canister.

4. Photographic Experiment Film Compatibility

Conclusion - In some cases, film fogging occurred when the emulsion was exposed to certain materials. Although test results were inconclusive, film plate fogging may have been caused by chemical contamination from film container materials and associated equipment. Film handling and exposure mechanisms affect the quality of the data recorded on the emulsion. Film plates were not always extracted in flight because the flight hardware configuration was slightly different than the unit that was successfully tested before flight. Also, the changing of film from that tested to other film late in the program precluded testing with the new film and may have reduced the scientific results.

Recommendation - Photographic experiments should be operationally tested with flight film to assure compatibility of hardware and film and to verify that the desired data can be recorded on the emulsion.

5. Film Radiation Protection

Conclusion - Passive dosimeters within the film vault indicated radiation levels that were inconsistent with those measured outside the vault (indicating higher than would be expected). The operational films do not exhibit the degradation that would be anticipated at the indicated level.

Recommendation - Further analysis of the radiation indicated by the film and by the dosimeters is required. If higher levels are determined to have been present within the vault, then a program should be initiated to determine the reasons for the higher radiation level, so that the necessary film protection can be provided in future space flights.

6. Hardware Safety Features

Conclusion - Provision of safety features that preclude hardware damage when more probable failures or procedural errors occur could avoid equipment and data loss. They would permit a return to operational capability after problem resolution. If fuses had been replaceable or had there been a circuit breaker, complete experiment operational capability could have been restored. If all motors had been equipped with appropriate limit switches, burnout could have been avoided when mechanisms bound.

Recommendation - Build in safety features (e.g., fuses or circuit breakers, interlocks, limit switches) to protect the hardware.

7. Crew Restraints

Conclusion - Restraint harnesses loosened and did not provide sufficient rigidity. Harness modifications and a rigidizing kit were developed and proved successful during later uses. Use of Skylab restraint experience and the appropriate simulations (e.g., air tables, neutral buoyancy tank, etc) can minimize crew restraint problems on orbit and greatly increase the crew's capabilities.

Recommendation - Give special consideration to crew restraints and verify designs with good simulations of zero-g operation.

B. Crew Capabilities

Conclusion - The Skylab crews demonstrated capabilities for handling equipment and performing tasks well beyond the preflight constraints and guidelines.

Recommendation - For future programs, the guideline capability of the crewmen should be expanded to reflect Skylab experience. Specifically:

Hardware with a moment of inertia greater than 65 $lb\text{-}in\text{-}sec^2$ can be easily handled by a single crewman; and

Safety constraints (e.g., limitations on having equipment like scientific airlock experiments set-up during other operations) should be established recognizing the maneuverability demonstrated by the Skylab crews.

SECTION IX. REFERENCES AND BIBLIOGRAPHY

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TABLE IX-1. EXPERIMENTS WITH APPLICABLE ICD's

CARRIER & EXP. NO.	EXPERIMENT ICD's			
	MECHANICAL	ELECTRICAL	I & C	CM RETURN
MDA				
S009	13M12191	40M35652	----	13M13509
M512	13M12161	40M35625	----	13M13507
M518	13M12161	101E439	50M13148	13M13507
PROTON SPECTROMETER	13M13513	40M35664	50M16134	----
AM				
D024	13M12024	----	----	13M13508
M512	13M13543	----	----	----
IU				
S150	13M07394	40M35670A	50M16133	----
	----	40M35678A	----	----
OWS				
S019/S183	13M13522	----	----	----
S183	13M13521	40M35684	50M16146	13M13523
T003	13M12231	----	----	13M13511
T013	13M12321	40M35624	50M16135	----
T020	13M12261	----	----	----
	13M13538	----	----	----
T027	13M12311	40M35606	13M12353	13M13510
T002	13M13535	----	----	----
CM				
T002	13M13542	----	----	----
M512	13M13507			
M555	13M13507	40M35753		
Biomed Storage	13M13516			
Film to Vault	13M13519			
Film to CM Return	13M13520			
16mm DAC	13M13546			
Portable Hi Intensity Photo Lamp	13M13410			

APPENDIX A - PHOTOGRAPHY

A. Introduction

Corollary experiment film required environmental protection (i.e., radiation shielding and temperature and humidity control) to produce useable scientific results after several months in orbit. This protection was provided by storing the film within the OWS film vault, which provided a controlled environment of radiation throughout the entire mission and humidity control during the unmanned storage periods. Temperature passively was controlled by the OWS thermal control system. Similarly, humidity in the film vault during the manned visits was whatever resulted from mixing of cabin atmosphere into the vault when the doors were open. Thus when the meteoroid shield was lost and OWS temperatures went to over 120°F, the film was exposed to conditions considerably beyond the premission limits.

This appendix summarizes the premission definition of the Skylab environment, the effects of the environment on films, film vault design, and orbital operations relative to corollary experiment films.

B. Skylab Environment

1. Radiation. The environmental parameters that affect film are radiation, temperature, and humidity. Radiation poses the greatest hazard to the films. The radiation environment consists of charged particles from three sources: 1) cosmic rays from intergalactic space, 2) protons from solar flare proton events, and 3) electrons and protons trapped in the magnetic field of the earth. Galactic Cosmic Radiation (GCR) includes energetic charged particles such as protons, alphas, and other stripped nuclei with energies that range from 10 MeV (million electron volts) up to at least 10^{15} MeV. The daily dose rate ranges from 11.6 millirad per day behind 1 gram per square centimeter of aluminum to 9.6 mrad/day behind 50gm/cm^2. The energy level is so high that there is no practical method for eliminating the GCR damage, and a value of about 10 mrad/day was predicted as the GCR dose.

Solar flare proton events that envelope the earth are infrequent and are of unpredictable magnitude. To attempt to provide shielding for such events was not economical because of the low probability of a significant occurrence. Therefore, efforts were primarily concerned with protecting the films from the effects of the electrons and protons trapped in the earth's magnetic field. The regions where these particles are trapped are called the Van Allen belts.

The field that creates the Van Allen belts is neither uniform nor geometrically centered about the earth's spin axis. This means that at a constant orbital altitude, such as Skylab's, the intensity of the field will vary. It is this type of variation that creates an area of high field strength and thus a high particle density, called the South Atlantic Anomaly (SAA). It is in the SAA that the flux of energetic protons and electrons presented the shielding requirements for Skylab. The skin of the Skylab is sufficient to nearly eliminate all radiation caused by trapped electrons internal to the Skylab. Figure A-1 indicates the effect of the shielding of the Skylab and its film vaults on the relative abundance of the various types of radiation. In each case the most predominant form of radiation is listed first.

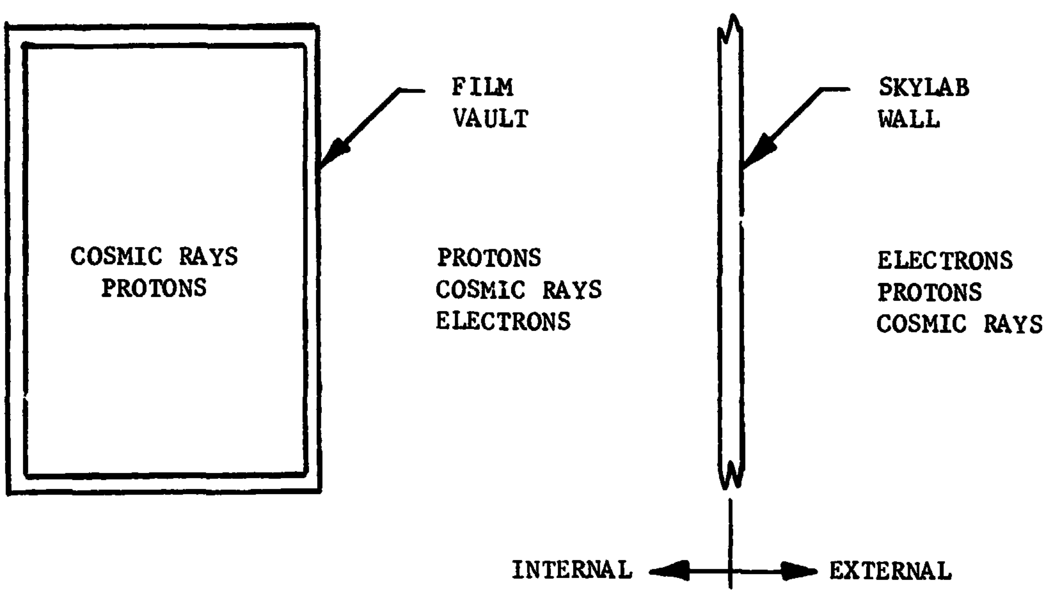

FIGURE A-1 SKYLAB RADIATION ENVIRONMENT

The design of the film vault was determined by the trade off of launch weight, and the radiation protection that would keep film degradation to a level that would not mask the data on the film.

2. Temperature and Humidity. The predicted temperature and humidity varied throughout the prelaunch, launch, orbital habitation, and orbital storage periods. A ground cooling system maintained the OWS interior between 40°F and 55°F from close-out to launch. During the manned periods the temperature was to be maintained between 65° and 80°F, with the lower limit dropping to 45°F during the storage period. The relative humidity of the OWS interior during prelaunch was predicted to be near zero because it was pressurized with dry nitrogen. During habitation, moisture was added by the astronauts

presence, and the environmental control system was to maintain the relative humidity between 27 and 65 percent with 45 to 55 percent expected during most of the manned period. During orbital storage the OWS humidity was starting between 27 and 100 percent and fall to between 4 and 16 percent near the end of the period.

C. Effect of the Environment on Films

With the environment established, the next step was to evaluate its effect on the films, and determine if the resultant degradation was acceptable to the principal investigators. To accomplish this, several test programs were initiated. Corollary Experiment Film Environment Degradation Tests, ED-2002-1109, were performed to evaluate the effects of environmental storage factors of time, temperature, and relative humidity. Similarly, Skylab Radiation Film Studies, ED-2002-1110, were performed to evaluate the photographic degradation due to radiation on Skylab experiment films.

The humidity and temperature testing involved placing a latent image on samples of the films, then subjecting them to temperatures ranging from 80°F to 120°F and humidity ranging from 20 percent to 90 percent. The degradation of this latent image, determined by densitometry of the processed film, was used as the judging criteria. All test environmental conditions operated at 90 percent relative humidity were found to be unacceptable as was a storage temperature of 120°F. Storage temperatures as high as 100°F were considered acceptable for short periods of time, if low humidity was maintained. The effect of time, temperature and humidity on the film are factors that are inseparable and can only be varied in their proportional effects. As time elapses the speed and contrast of an emulsion generally decreases, the fog level increases, and the maximum attainable density decreases. Low humidity primarily affects the physical characteristics of the film rather than its photographic qualities. Specifically the film may develop cracks or tears in the emulsion, the base may become brittle and break, and static discharge may occur if the film is advanced in the camera while it is dry. High humidity may cause sticking of the layers or even separation of the emulsion from the base.

The radiation tests consisted of determining the degradation in photographic response caused by Cobalt 60 (Co60) gamma rays. Film samples were irradiated at the JSC High Range Calibration Test Facility using a ten curie Co60 gamma ray source. Dosages varied, based upon the expected sensitivity of the film, from 0.1 Rad to 48 Rad. The film was then exposed with a test image at wavelengths spectrally representative of the Skylab film type (i.e., x-ray, ultraviolet, visible, and infrared). The film was then processed and analyzed to produce the characteristic curve or the H&D curve after Hurter and Driffield. This allows the determination of: the "gross fog" or the density due to the base material plus the fog of the film; gamma or the slope of the straight line portion of the H&D curve; and the

resolution characteristics. The final determination of acceptability of film responses after irradiation was based upon a subjective assessment of the film test samples by the experiment Principal Investigators.

The general effect of all high-energy radiation on a photographic film is an increase in background density (gross fog), and a reduction in gamma and film speed. The increase in background density causes loss of detailed information in the low light level region because of masking by the fog. The total range of contrast available on a film emulsion is reduced by the rise in background density. The reduction in gamma causes a decrease in contrast between areas of varying light level exposure that may, in some cases, cause a loss of detail in the recorded information. The reduction in film speed causes the appearance of underexposure of the photograph.

D. Film Vault Design

With the environment established and the limits for each factor determined, the design of the film vault became a trade-off between launch weight and the mass required to provide the necessary protection. The allowable radiation dose was established by evaluating the results of the Radiation Test Program and additional discussions with some of the PIs. From this value the Galactic Cosmic Ray dose was deducted since they would penetrate, without significant loss of energy, any shielding that Skylab could offer. Deductions were made for the periods of time duing which the film was out of the film vault, being transported in the Command Module and in operation. This resulted in an allowable radiation dose that determined the shielding requirement for the film vault. Several iterations of assuming a preliminary shielding thickness then determining the radiation spectra within the vault due to the environment resulted in establishing the final shield thickness.

The final design of the OWS film vault employed one large aluminum casting with 12 drawers, 2 with 0.25 in. of shielding; 6 with 1.9 in. and 4 with 3.4 in. (see figure A-2). It occupied a total envelope approximately 54 in. high, 40 in. wide, and 26 in. deep. Its weight, without film, was approximately 2250 lbs.

The front of the vault was closed by two doors hinged in the center of the vault face. During launch the doors were secured by bolts to the main body of the vault. This eliminated the need for massive hinges that would not be needed in the zero-g environment of space. While on orbit the vault doors were held closed by suitcase type latches.

The inside of the doors had indentations, both to provide the proper amount of shielding, and to provide room for the mounting of potassium thiocyanate salt pads. The salt pads possessed the property of absorbing or releasing moisture to the surrounding atmosphere,

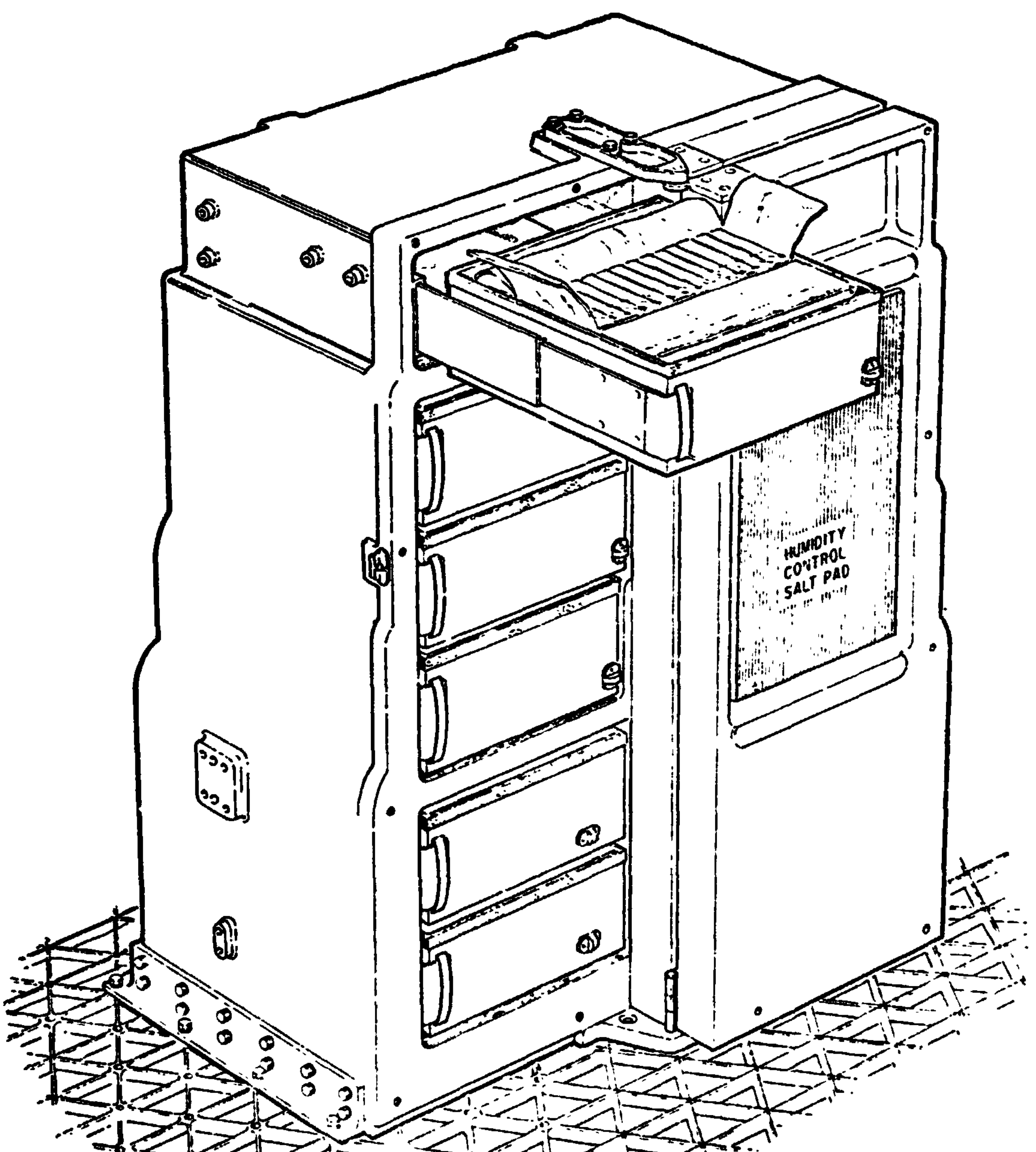

FIGURE A-2 SKYLAB FILM VAULT Fu COROLLARY EXPERIMENT FILM

depending upon its relative humidity. Thus the quantity of salt pads contained within the vault along with a controlled leakage of the doors was to maintain a relative humidity of 45% ± 15%.

E. Orbital Operations

The Saturn Workshop was launched at 17:30:00 GMT on DOY 134. At approximately 69 seconds after lift-off the meteoroid shield on the +Z side of the vehicle and one solar array wing separated from the workshop. All other systems operated nominally placing the workshop in the desired 235 nautical mile orbit. The vehicle was then maneuvered into solar inertial attitude and the temperature rose above operating limits. At 13 hours into the flight the vehicle was pitched up toward the sun to reduce the solar incidence angle on the workshop. A delicate balance between temperature and power was maintained by maneuvering the vehicle until the launch of SL-2, eleven days after the launch of SL-1. On the second manned mission day the crew deployed the parasol out the solar SAL and the temperature begain to drop.

The temperature profile for the OWS film vault is shown in figure A-3. There was no temperature sensor within the film vault so an approximately technique was developed that averaged the temperatures indicated by several adjacent sensors and added a correction factor of 5°F. On DOY 148 a check of this technique made using the M487 digital thermometer indicated good correlation.

This period of high temperature and low humidity was cause for concern for many of the experiments employing film that was stowed in the OWS film vault. Results of the Film Degradation Tests were reviewed along with "glove box" data provided by the film manufacturer, Kodak. It was determined that the low humidity, low pressure, nitrogen atmosphere provided near optimal storage conditions for the elevated temperatures. The potential for color shift due to temperatures above 120°F indicated that resupply of the EREP color visible and IR films was advisable. The results of previous thermal tests had shown erratic results for SC-5 and 103a-0 films making their resupply highly desirable. The experiment films finally selected for resupply were S019, S183, S190A, and S190B. The S009 Nuclear Emulsion was determined to require resupply, but due to space and weight considerations was delayed until SL-4. The initial S009 package was exposed and returned on SL-2 but the heat had fused the layers of film rendering the data unrecoverable.

It was feared that the low humidity would dry out the film to the point that emulsion cracking and static discharge might become a problem. It was suggested that water might be introduced to the film vault through the use of a moist towel, thus raising the humidity allowing reconstitution of the film. The final decision, again based upon information from Kodak indicating that any drying would be minimal and an edge phenomena, was that the rise in humidity due to activation

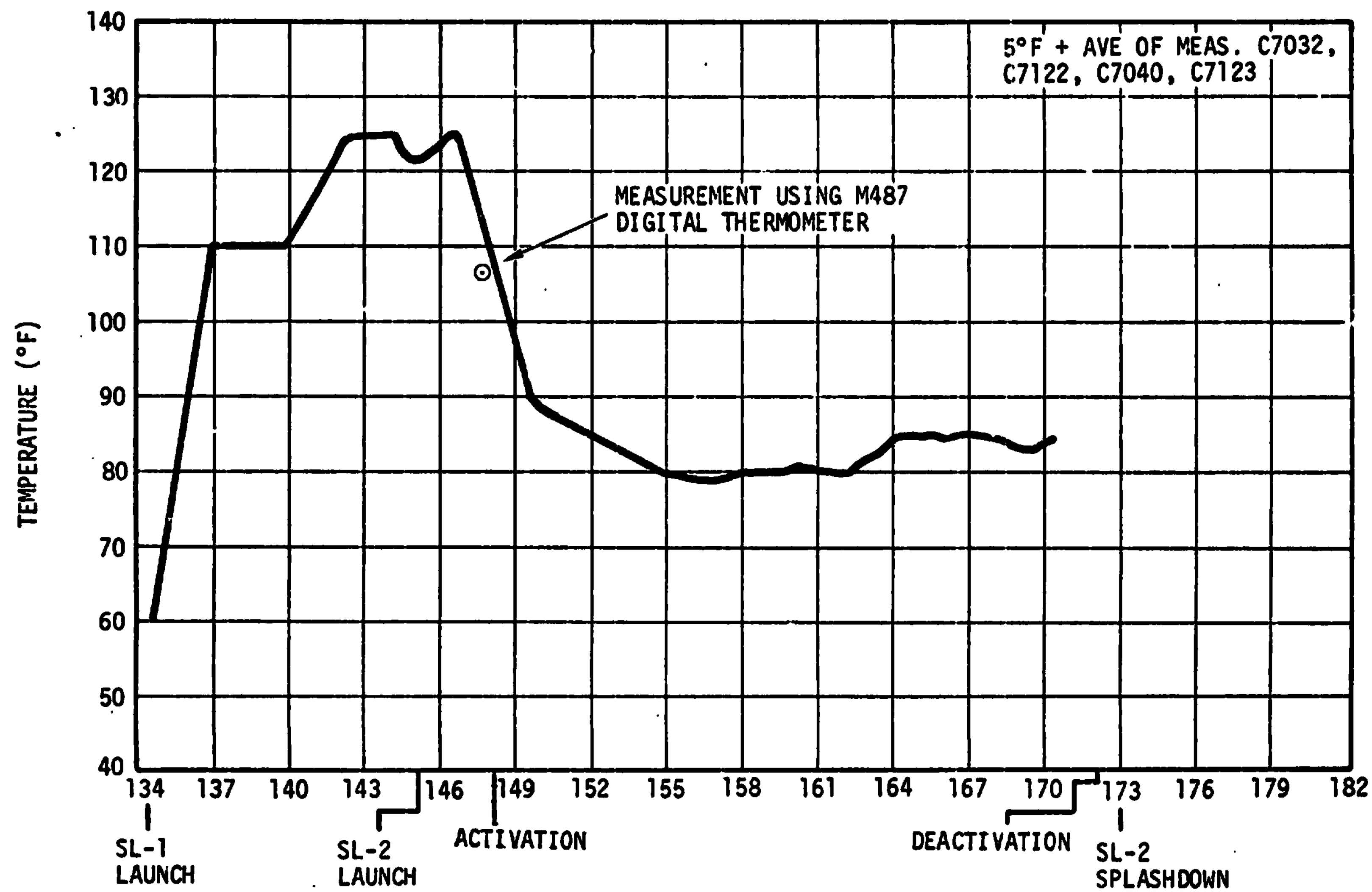

FIGURE A-3 OWS FILM VAULT TEMPERATURE PROFILE (ESTIMATED)

of the cluster and the period of time between activation and anticipated film usage would be adequate for reconstitution. The effect on the remaining film was exhibited by the 16mm DAC film. It was found necessary to remove the lead 2 meters prior to threading to prevent jamming.

Several corollary experiments experienced anomalies related to their photography: S019 experienced several magazine jams, the S183 carrousel launched on SL-1 was considered degraded by the high heat and the resupplied carrousels (both SL-2 and SL-4) jammed, and the S183 16mm film magazine on SL-4 jammed. These were individual experiment anomalies, but one anomaly that plagued several experiments was the out-of-focus condition of Nikon 02. The first roll of film shot on SL 4 with Nikon 02 was in focus, but all subsequent rolls were out of focus. Analysis and testing showed that the closest approximation to the flight condition was accomplished by removing the internal film pressure plate. This problem degraded the data for S073 and S063, both ozone and airglow studies.

Preliminary evaluation of the radiation protection afforded by the film vault has resulted in a degree of uncertainty. Two sets of passive dosimeters were placed in drawers B and F and a personal radiation dosimeter was placed in drawer A by the SL-2 crew. One set of passive dosimeters and the PRD were returned by the SL-2 crew, and the other 2 passive dosimeters were returned at the end of SL-3. All the dosimeters in the vault indicated a rad dose approximately a factor of 2 greater than the pre-mission projections. Several explanations have been offered. On DOY 328, during activation by the SL-4 crew, the PLT reported finding the film vault door ajar. The amount of opening was about one foot and the time of opening was not known. It is natural to assume that this opening (and any other similar openings) may account for the discrepancy. However, the doses are too consistent to have been influenced by chance, and the additional dose would have required the vault doors to be open on a nearly continuous basis.

Another explanation is that the energy spectrum of the environment may be "harder" than predicted, containing fewer low energy particles and more high energy radiation. Thus the protection afforded by the vault would not be as effective as anticipated, yet the dosimeters outside the vault would indicate, as they did, a total radiation level on the order of what was predicted. However, there seems to be no basis for nearly tripling the cosmic ray dose rate as indicated by the vault dosimeters. Presently there appears to be no explanation for the large under-estimate of the film vault dose.

APPENDIX B - ENVIRONMENTS

This appendix briefly summarizes the environmental assessments performed prior to the Skylab missions and presents the actual conditions encountered during the missions as they relate to the corollary experiments. The environments considered include temperature, humidity, pressure, atmospheric gas composition, vibration, shock, acceleration, and radiation.

A. Premission Environmental Assessments

Environmental design criteria for Skylab modules and experiments were identified in the Cluster Requirements Specification (CRS), RS003M00003. Experiment environmental requirements were documented in the ERDs. Compatibilities of experiment designs with the CRS requirements were continuously monitored and significant discrepancies reported in the Experiment Compatibility Status Reports, Martin Marietta Corporation Reports ED-2002-471-1 through 32. Potential environmental problems were identified in the areas of dynamic and acoustic testing, on-orbit radiation and acceleration levels, and temperatures of anti-solar SAL experiment hardware. These were resolved by successive completion of appropriate tests, design or requirement changes, appropriate analyses, or requests for deviations from the requirements. Approved deviations were incorporated into Appendix K of the CRS.

The loads criteria for all external and internal components, including experiments, mounted on the Skylab structure were identified in MSFC memorandum IN-ASTN-AD-70-1 and were incorporated in the CRS by reference. The original criteria were based upon Saturn V launch data modified by analysis of structural differences in Skylab. Vibration and acoustic testing of the OWS at JSC generally verified the originally specified loads. However, exceptions were found where the test results exceeded specified loads, particularly for equipment mounted on the OWS wall or floor. An exceedance study compared experiment test requirements with the revised loads. The only MSFC experiment with test levels lower than the new loads was the T013 Force Measurement Unit mounted on the OWS tank wall. Since the T013 qualification level was only 2 db below the new criteria below 70 Hz and the amplification factors estimated for the FMU mounting brackets were very conservative, the previous qualification test was accepted.

A comprehensive assessment of environmental compatibility of the Skylab experiments integrated by MSFC (other than ATM) was performed in the spring of 1972. The results were coordinated with the experiment developers and responsible NASA organizations to achieve an acceptable resolution. The potential problems identified for the

MSFC corollary experiments were all resolved on the basis of additional analyses and rationale or approval of deviations prior to the Corollary Experiment DCR.

An assessment of experiment acceleration limits resulted in (1) a constraint not to perform Experiment T020 during vehicle maneuvers, and (2) requests for acceleration data for experiments M479, M551, M553 and M555. When the experiments using the M518 furnace were approved, acceleration data for these was also requested.

Thermal analyses of the anti-solar SAL experiments showed that hardware extended beyond the OWS skin (e.g., S019 Articulated Mirror used by S183, T027 Photometer, etc.) would cool rapidly and would require several hours to warm to above the cabin atmosphere dew point to permit demount without condensation. After evaluating repressurization with nitrogen a less costly desiccant system was approved. This precluded condensation from the repressurizing gas but left the potential for introducing cabin atmosphere into the canister during demount. To avoid condensation plans were established with the JSC flight planners to leave the experiments mounted for the required warm-up time, or, if scheduling necessitated earlier removal, procedures were established for two crewmen to demount the experiment with the second crewman immediately installing the end cap to minimize entry of cabin atmosphere into the canister.

B. Mission Environments

A comparison of CRS requirements to measured environmental values during the pre-habitation, habitation, and storage periods is presented in table B-1. The most significant environmental anomaly concerned the high OWS temperatures during the first few days of SL-1 which resulted from the loss of the meteoroid/thermal shield during launch. The only corollary experiment equipment seriously degraded by the high temperature was film and the S009 Nuclear Emulsion, discussed in Appendix A.

Humidity was indicated as approaching 100% RH by local wall temperature measurements and measurements of the cabin atmosphere dewpoint as it passed through the purification system. The primary concern was the possibility of condensation on the S190A window, but the crew never observed condensation around the window, even at times when the measurements indicated 100% relative humidity. Humidity variations apparently had no detrimental effects on the corollary experiments.

OWS pressure was cycled down to 0.3 psia during the pre-habitation period to purge any possible toxic gasses from the over-heated polyurethane OWS insulation. Pressure for the remainder of

TABLE B-1 COMPARISON OF SKYLAB MEASURED ENVIRONMENTAL EXTREMES WITH CRS REQUIREMENTS FOR EXPERIMENT HARDWARE

MISSION PHASE / ENVIRONMENT & MODULE	LAUNCH & ASCENT		PRE-HABITATION		HABITATION & ORBITAL STORAGE	
	CRS REQ'T	MEASURED VALUES	CRS REQ'T	MEASURED VALUES	CRS REQ'T	MEASURED VALUES
Int. MDA Temperature	40-90°F	50-75°F	40-90°F	45-70°F	Wall: 50-90°F Atmos: 60-90°F (Orb. Stor. 40-90)	Manned 52-72°F Orb. Stor. 46-71°F
Int. OWS	40-85°F	50-70°F	40-90°F	70-140°F	Wall: 55-105°F Atmos: 60-90°F	71-85°F* 63-98°F
Relative Humidity	5%	Estimated: 5%	5%	5%	30-85%	MDA: 36-81% OWS: 5.5*-60%
Pressure	MDA: 14.7 psia to 0.5 psia OWS: 26 psia	MDA: 14.7 psia to 0.5 psia OWS: 26 psia	0.5 - 6.0 psia	0.3 psia - 5.0 psia	5.0 - 6.0 psia	Manned 4.8 - 5.4 psia Orb. Stor. 0.3 - 5.1 psia
Atmosphere Comp.	MDA: 80% N_2, 20% O_2 OWS: 100% N_2	80% N_2, 20% O_2 100% N_2	100% N_2 to 100% O_2	100% N_2 to 74% O_2, 26% N_2	70% O_2, 30% N_2 to 100% O_2	60% O_2, 40% N_2 to 79% O_2, 21% N_2 By Vol.
Vibration	Ref: IN-ASTN-AD-70-1	Less than IN-ASTN-AD-70-1	N/A	N/A	N/A	N/A
Shock	N/A	N/A	MDA: IN-ASTN-AD-70-1 OWS: N/A	MDA: Not Measured OWS: N/A	N/A	N/A
Acceleration	4.7g	4.7g	N/A	N/A	N/A	N/A
Radiation	N/A	N/A	0.5 rads/day	0.2 rads/day	0.5 rads/day	0.2 rads/day

* The mean OWS temperature was approximately 130°F on initial entry and prior to the deployment of the parasol shield the first day of habitation.

the missions was essentially nominal. The purge cycles, in particular the rate of pressure reduction, may have contributed to the rupture of the ED78 diaphragm but no other adverse effects of internal pressure are known. Atmosphere composition was essentially nominal.

Radiation dosage was less than predicted in the OWS, but the dosimeters in the film vault recorded a higher-than-predicted dose, as discussed in Appendix A.

APPROVAL

MSFC SKYLAB COROLLARY EXPERIMENTS SYSTEMS
MISSION EVALUATION REPORT

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has been reviewed and approved for technical accuracy.

Henry B. Floyd

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Experiment Development and
Payload Evaluation Project Office

Rein Ise

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